(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 708 068 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
27.11.2024 Bulletin 2024/48

(21) Application number: **19210152.5**

(22) Date of filing: **22.10.2015**

(51) International Patent Classification (IPC):
A61B 5/00 *(2006.01)* ***A61M 21/00*** *(2006.01)*
A61G 7/008 *(2006.01)* ***A61G 7/015*** *(2006.01)*
A61G 7/057 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
A61G 7/018; A61B 5/4809; A61B 5/4818; A61B 5/6892; A61G 7/001; A61G 7/008; A61G 7/05776; A61M 21/02

(54) **DYNAMIC APNEA THERAPY SURFACE**

DYNAMISCHE APNOETHERAPIEOBERFLÄCHE

SURFACE DE TRAITEMENT DES APNÉES DYNAMIQUES

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **31.10.2014 US 201462073565 P**

(43) Date of publication of application:
16.09.2020 Bulletin 2020/38

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
15190984.3 / 3 015 058

(73) Proprietor: **Hill-Rom Services, Inc.**
Batesville, IN 47006-9167 (US)

(72) Inventors:
- **RIBBLE, David Lance**
  Batesville, IN 47006-9167 (US)
- **HOOD, Michael Scott**
  Batesville, IN 47006-9167 (US)
- **HOWELL, Charles A.**
  Batesville, IN 47006-9167 (US)
- **AGDEPPA, Eric D.**
  Batesville, IN 47006-9167 (US)

(74) Representative: **Reddie & Grose LLP**
The White Chapel Building
10 Whitechapel High Street
London E1 8QS (GB)

(56) References cited:
WO-A1-2012/129397
WO-A1-2014/149392
WO-A2-2013/177338
JP-A- 2007 222 463
US-A1- 2004 103 475
US-A1- 2013 267 791
US-A1- 2014 309 483

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Description

[0001] This disclosure relates generally to dynamic person support surfaces, devices, systems, and methods configured to provide apnea therapy and/or therapy for other disorders. An exemplary system known in the art is described in international patent publication number WO 2014/149392 A1, filed in the name of Hill-Rom Services, Inc., which describes a dynamic support system that is configured to control the configuration of a sleep surface based at least in part on patient data sensed by one or more sleep sensors. In one embodiment, a sleep surface is formed of a closed air system that induces the user's body to rotate laterally when sleeping to facilitate preventing or limiting the incidence of sleep apnea. Another exemplary system known in the art is described in international patent publication number WO 2012/129397 A1, which describes apparatus that monitors orientation of a patient, and alerts the patient when the patient has turned onto his or her back for a time longer than a minimum threshold period. Another exemplary system known in the art is described in US patent application publication number US 2004/103475 A1, which describes an adjustable bed having a tilt unit operable to perform an operation of tilting a bed section laterally, and a control unit that is operable to control the tilt unit based on a result of a judgement by a judgement unit.

[0002] The present disclosure discloses one or more of the following features alone or in any combination. The present invention is defined in the appended claims, by a dynamic person support system according to claim 1, and dependent claims 2-9.

[0003] In some embodiments, the lateral rotation actuator may include an electromechanical device configured to drive lateral rotation of the independently rotatable support planes. Alternatively or additionally, the lateral rotation actuator may include a plurality of inflatable bladders supporting the independently rotatable support planes and an air supply operably coupled to the inflatable bladders.

[0004] The control unit is configured to compute the maximum supine position duration as a function of an apnea-hypopnea index (AHI) value of the monitored human subject. The control unit is configured to compute the maximum supine position duration based on a first apnea-hypopnea index (AHI) value and a second AHI value. The first AHI value is determined while the human subject is in a supine position and the second AHI value is determined while the human subject is in a non-supine position.

[0005] In some embodiments, the dynamic person support system may include a sensor in communication with the control unit. The control unit may be configured to receive a sensed value from the sensor and determine the maximum supine position duration based on the sensed value. The sensed value may be indicative of an apnea-hypopnea index (AHI) of the monitored human subject. Alternatively or additionally, the sensed value may be indicative of a sleep state of the monitored human subject. The control unit may be configured to adjust the maximum supine position duration in response to the sensed value. Optionally, the control unit may be configured to increase the maximum supine position duration in response to the sensed value being below a threshold value. Further optionally, the control unit may be configured to decrease the maximum supine position duration in response to the sensed value being above a second threshold value.

[0006] A dynamic person support system may include a person support surface that may have a pair of laterally spaced support segments. At least one of the support segments may include a lateral rotation apparatus. The lateral rotation apparatus may have a plurality of independently rotatable longitudinally arranged support planes and a lateral rotation actuator that may be operably coupled to one or more of the support planes. A first occupant sensor may be coupled to the support segment comprising the lateral rotation apparatus. A second occupant sensor may be coupled to the other support segment. A control unit may include a processor and a non-transitory machine readable storage medium that may have a dynamic therapy routine. The dynamic therapy routine may include instructions executable by the processor to cause the control unit to control the operation of the lateral rotation apparatus by: with the first occupant sensor, detecting a state of a first human subject on the support segment comprising the lateral rotation apparatus; with the second occupant sensor, detecting a state of a second human subject on the other support segment; and in response to the detected state of the first human subject and the detected state of the second human subject, controlling the lateral rotation actuator of the lateral rotation apparatus.

[0007] In some embodiments, the lateral rotation actuator may include an electromechanical device configured to drive lateral rotation of the independently rotatable support planes. Alternatively or additionally, the lateral rotation actuator may include a plurality of inflatable bladders supporting the independently rotatable support planes and an air supply operably coupled to the inflatable bladders. The second occupant sensor may be configured to detect a sleep state of the second human subject and the control unit may be configured to delay operation of the lateral rotation actuator until the second human subject is detected as being asleep.

[0008] In some embodiments, the first occupant sensor may be configured to detect a position of the first human subject relative to the support segment comprising the lateral rotation apparatus and the control unit may be configured to delay operation of the lateral rotation actuator if the detected position of the first human subject is not substantially on the support segment comprising the lateral rotation apparatus. If desired, the control unit may be configured to control the lateral rotation apparatus based on a combination of criteria including at least one criterion relating to the first human

subject and at least one criterion relating to the second human subject. The control unit maybe configured to delay operation of the actuator until both the first human subject and the second human subject are detected as being asleep.

[0009] A lateral rotation apparatus may include a person support surface that may have head, torso and leg segments each of which may have an independently rotatable person support plane. A lateral rotation actuator may be operable to rotate the head segment to a head tilt angle in the range of about 7 to about 30 degrees relative to a horizontal support plane and to rotate the torso segment to a torso tilt angle that is within a range of about 5 degrees to about 10 degrees less than the head tilt angle.

[0010] In some embodiments, the lateral rotation actuator may include a plurality of inflatable bladders, and each person support plane may be supported by an inflatable bladder. Alternatively or additionally, the lateral rotation actuator may include an electromechanical device. The lateral rotation actuator may be operable to rotate the torso segment to a torso tilt angle in the range of about zero to about 25 degrees. The lateral rotation actuator may be operable to rotate the head segment to a head tilt angle in the range of about 10 to about 15 degrees. The lateral rotation actuator may be operable to rotate the torso segment to a torso tilt angle in the range of about 5 to about 10 degrees. The lateral rotation actuator may be operable to rotate the leg segment to a leg tilt angle in the range of about 0 to about 5 degrees. The lateral rotation apparatus may include a control unit that may control inflation of the bladders to maintain a differential between the head tilt angle and the torso tilt angle. For example, the differential may be in the range of about 5 to about 10 degrees. The torso segment may be longitudinally longer than the head segment and the leg segment may be longitudinally longer than the torso segment. For example, the head segment may have a longitudinal length of about 40.6 centimetres (16 inches), the torso segment may have a longitudinal length of about 61.0 centimetres (24 inches), and the leg segment may have a longitudinal length of about 101.6 centimetres (40 inches).

[0011] In some embodiments, the person support surface may include a support material having a density and the head tilt angle may be a function of the density of the support material. Alternatively or additionally, the torso tilt angle may be a function of the density of the support material.

[0012] The invention will now be further described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a simplified schematic view of at least one embodiment of a person support system, including a simplified top view of a dynamic therapy surface configured for multiple occupants;

FIG. 2 is a simplified perspective view of at least one embodiment of the dynamic therapy surface of FIG. 1, showing at least one embodiment of a lateral rotation apparatus supporting one of the occupants in a therapy position on a segment of the dynamic therapy surface;

FIG. 3 is another simplified perspective view of at least one embodiment of the dynamic therapy surface of FIG. 1, showing at least one embodiment of the lateral rotation apparatus supporting the occupant in the therapy position on a different segment of the dynamic therapy surface;

FIG. 4 is a simplified block diagram of at least one embodiment of the control unit and other components of the person support system of FIG. 1;

FIG. 5 is a simplified flow diagram of at least one embodiment of a method for controlling a lateral rotation apparatus such as the lateral rotation apparatus of FIG. 1 based on inputs relating to multiple occupants of a dynamic therapy surface such as the dynamic therapy surface of FIG. 1;

FIG. 6 is a simplified flow diagram of at least one embodiment of a method for controlling a lateral rotation apparatus such as the lateral rotation apparatus shown in FIG. 1 based on supine position duration of an occupant of a dynamic therapy surface such as the dynamic therapy surface of FIG. 1;

FIG. 7 is a simplified schematic view of at least one embodiment of an adverse event mitigation system, which may include portions of the person support system of FIG. 1 and/or other features disclosed herein;

FIG. 8 is a simplified side perspective view of at least one embodiment of a person support apparatus and a person support surface, each or either of which may include one or more of the features disclosed herein;

FIG. 9 is a simplified perspective view of at least one embodiment of a dynamic therapy surface that may include one or more of the features disclosed herein, taken from a viewpoint looking toward a longitudinal side of the dynamic therapy surface;

FIG. 10 is another simplified perspective side view of the dynamic therapy surface of FIG. 9, taken from a viewpoint looking toward a longitudinal side opposite the longitudinal side of the viewpoint of FIG. 9;

FIG. 11 is a simplified longitudinal elevational view of the dynamic therapy surface of FIG. 9, taken from a viewpoint looking toward the same longitudinal side as the viewpoint of FIG. 10;

FIG. 12 is a simplified lateral elevational view of the dynamic therapy surface of FIG. 9, taken from a viewpoint near a head end (e.g., element 1118) of the dynamic therapy surface;

FIG. 13A is a simplified perspective view of at least one embodiment of a dynamic therapy surface as disclosed herein;

FIG. 13B is a simplified top view of the dynamic therapy surface of FIG 13A, looking in the direction labelled 13B in FIG. 13A;

FIG. 13C is a simplified longitudinal side view (viewed along the longer side) of the dynamic therapy surface of FIG. 13A, looking in the direction labelled 13C in FIG. 13B;

FIG. 13D is a simplified lateral side view (viewed along the shorter side, or end) of the dynamic therapy surface of FIG. 13A, looking in the direction labelled 13D in FIG. 13C;

FIG. 14 is a simplified schematic view of components of an exemplary dynamic support system that may include one or more of the features disclosed herein; and

FIG. 15 is a simplified schematic diagram of a method for monitoring sleep activities of a person positioned on a dynamic therapy surface, which may include one or more of the features disclosed herein.

[0013] Technologies for laterally rotating a support surface as a treatment or therapy for sleep apnea and/or other disorders are disclosed in PCT Application No. PCT/US2013/042313 filed May 22, 2013; PCT Application No. PCT/US2014/018033, filed February 24, 2014; U.S. Utility Application No. 14/454,961 filed August 8, 2014; and U.S. Design Patent No. 29/498,872. These and other similar technologies can be applied to circumstances in which multiple persons utilize a common sleep surface. These technologies can be improved by controlling a common support surface based on inputs from both the apnea sufferer and a second individual positioned on the common support surface. Alternatively or in addition, these technologies can be improved by controlling the support surface based on a maximum allowable supine sleep position duration. For example, whereas current approaches may strive to eliminate all supine sleep activities in order to reduce a person's apnea-hypopnea index (AHI) to below a threshold value), the control methods disclosed herein, which manage a dynamic sleep surface to a specified maximum supine sleep position duration value, can be applied to achieve that same goal with less aggressive therapy.

[0014] Referring now to FIGS. 1-3, a person support system 100 includes a person support surface 102, a lateral rotation apparatus 108, and a control unit 156. A number of occupant sensors 140, 142 are in communication with the control unit 156 (e.g., by wired, wireless, optical, or other signal communication mechanism). The illustrative person support surface 102 includes a pair of laterally spaced support segments 104, 106, although other embodiments may only include a single support segment (e.g., support segment 104). At least one of the support segments 104, 106 is configured as or includes a lateral rotation apparatus 108. As described in more detail below, the illustrative lateral rotation apparatus 108 includes a number of different support sections, including independently rotatable longitudinally arranged support planes 110, 112, 114 and lateral rotation sections 116, 118, 120. The lateral rotation sections 116, 118, 120 may be embodied as, for example, a non-inflatable support material, such as foam, or as inflatable bladders, or as a combination of a non-inflatable support material and bladders. FIGS. 10-12 and 13A-13D, described below, show illustrative embodiments of a person support surface 102 and lateral rotation sections 116, 118, 120.

[0015] The lateral rotation sections 116, 118, 120 are coupled to the support planes 110, 112, 114 by linkages 122, 124, 126, 128, 130, 132, 134, and one or more lateral rotation actuators 136. The lateral rotation actuators 136 drive lateral rotation of the support planes 110, 112, 114. The operation of the lateral rotation actuators 136 is dynamically controlled by the control unit 156, as described in more detail below.

[0016] In some embodiments, the lateral rotation actuators 136 are powered (e.g., electronic or electromechanical) devices, such as electric motors or linear actuators, and the linkages 122, 124, 126, 128, 130, 132, 134 include, e.g., drive arms or output shafts. In other embodiments, the support sections 116, 118, 120 each include one or more inflatable bladders, which support the support planes 110, 112, 114, respectively; the actuator 136 is an air supply unit, and the linkages 122, 124, 126, 128, 130, 132, 134 are pneumatic couplings including, e.g., air supply lines 128, 130, 132, 134 and valves 122, 124, 126. In "air bladder" embodiments, the bladders 116, 118, 120 are selectively inflated and deflated by the air supply 136 via the pneumatic couplings 122, 124, 126, 128, 130, 132, 134. The inflation and deflation of the bladders 116, 118, 120 is dynamically controlled by the control unit 156 operating the air supply 136 to supply air to or extract air from the bladders 116, 118, 120, as the case may be, in response to inputs from the occupant sensors 140, 142. The air supply 136 delivers air to the bladders 116, 118, 120 via one or more supply lines 128, 130, 132, 134 and valves 122, 124, 126. The air supply 136 may be embodied as, e.g., a blower, a compressor, or a vacuum/blower. Any suitable configuration of air supply lines and valves may be used. For example, multiple air supply lines may be connected to a valve manifold, in some embodiments. The valves 122, 124, 126 may be electronically controlled, e.g., by the control unit 156, in some embodiments. The actuator(s) can be configured to operate slowly and quietly, in order to minimize disruption to any occupant on the bed. For instance, the actuator 136's rate of change may be controlled by algorithms taking inputs from one or more of the sensors 140, 142 or other sensors.

[0017] Illustratively, the support segment 106 is embodied as a support section having a single support plane 138. In other embodiments, the support segment 106 may include multiple different support planes. For example, the support segment 106 may be embodied in a similar fashion to the support segment 104 and may include another lateral rotation apparatus or another type of therapy device.

[0018] In some embodiments, the sensor 140 is operably coupled to the support segment 104 by a coupler 144, and the sensor 142 is operably coupled to the support segment 106 by a coupler 146. Each or either of the sensors 140, 142 may be attached to a surface of the support segment 104, 106, respectively, embedded in the respective support

segment 104, 106, or mounted to a frame or deck that supports the support segment 104, 106, (e.g., a frame or deck that is similar or analogous to the frame 80 or the deck 86 shown in FIG. 8). As such, the couplers 144, 146 may be embodied as, for example, screws, rivets, stitching, brackets, adhesive, or other suitable fasteners. Alternatively, one or more of the sensors 140, 142 may simply rest on a frame or deck surface, within a pocket or enclosure of the support segment 104, 106, etc. Still further, each or any of the sensors 140, 142 may be in communication with the control unit 156 but not directly coupled to the support surface 102. For instance, any of the sensors 140, 142 may be embodied in a mobile or wearable computing device, such as a smart phone, a tablet computer, a smart watch, smart jewellery (e.g., a smart bracelet), smart glasses, or as a wearable sensor, such as a smart textile, a "clip-on" sensor, or a body-worn sensor (e.g.,. an electrode). As such, each or any of the sensors 140, 142 may be associated with a person using the support surface 102 (e.g., person 1 or person), rather than being directly associated with the support surface 102 or a section thereof. In these embodiments, the links 144, 146 may represent logical associations of sensors 140, 142 with persons carrying the sensors 140, 142, rather than physical connections with the support surface 102. For example, a sensor identifier may be associated with a person by a user identifier (user ID), and the data identifying persons and associated sensors may be stored in memory of the sensor 140, 142 or another device (e.g., in an electronic file, mapping table, or database). Thus, when a sensor 140, 142 communicates state indicators 148, 152 to the control unit 156, the sensor communications may include the sensed information as well as the user ID of the person with whom the sensor 140, 142 is associated.

[0019] Each or any of the sensors 140, 142 may be embodied as a single sensor or an array or combination of multiple sensors (e.g., a pressure map). The sensors 140, 142 may be of the same type or of different types. The sensors 140, 142 may each be embodied as any suitable type of device that is capable of sensing an indicator of a state of a person positioned on the person support surface 102, and may include, e.g., a pressure sensor, a force sensor, a temperature sensor, an accelerometer, an inclinometer, a physiological or vital signs sensor, a microphone or other sound detector, a sleep sensor (e.g., any type of sensor that can detect an indicator of a person's sleep, including any of the foregoing), an array of any of the foregoing types of sensors, or any combination of any of the foregoing types of sensors and/or others sensors.

[0020] In operation, the sensor 140 detects state information about a person 1 situated on the support segment 104, and the sensor 142 detects state information about a person 2 situated on the support segment 106 (illustratively, with head supported by a pillow 4), over a fixed or variable time interval. Each of the respective person 1 and person 2 state information may include, for example, an indication of: whether the person is awake or asleep, the particular stage of the person's sleep (e.g., rapid eye movement (REM) phase or not), the person's position relative to the support segment 104 or 106 (e.g., in order for the control unit 156 to determine whether the person in a proper position for a therapy to be performed), the person's activity level, one or more physiological parameters of the person (e.g., blood pressure, blood oxygen saturation, heart rate, respiration rate, etc.) and/or other person state indicators. The system 100 can be programmed to automatically disable or terminate the rotation (e.g., apnea therapy) if the system 100 detects an adverse condition. Alternatively or in addition, the system 100 can terminate or suspend the rotation (e.g., apnea therapy) by a manual override (such as a switch).

[0021] The control unit 156 receives person1 state indicators 148 from time to time from the sensor 140, and receives person2 state indicators 152 from time to time from the sensor 142, by way of suitable communication links 150, 154 as shown in FIG. 4, described below. The control unit 156 includes electrical circuitry and/or computer components, as shown in FIG. 4, which are configured as a dynamic therapy system 162. Aspects of the dynamic therapy system 162 may be embodied in a similar fashion to the computer system shown in FIGS. 14-15, described below.

[0022] The illustrative dynamic therapy system 162 includes a multi-occupant control module 164 and a supine position control module 166. The modules 162, 164 may each be embodied as computer hardware, software, firmware, or a combination thereof. The multioccupant control module 164 causes the control unit 156 to read and analyze the person1 state indicator 148 and the person2 state indicator 152, execute control algorithms, and issue lateral rotation apparatus control signals 158 from time to time based on a combination of the person1 and person2 state indicators 148, 152. The supine position control module 166 causes the control unit 156 to read and analyze at least the person1 state indicator 148, execute control algorithms, and issue lateral rotation apparatus control signals 158 from time to time based on at least the person1 state indicator 148 in combination with maximum supine position duration information stored in e.g., a memory accessible by the control unit 156.

[0023] The control unit 156 transmits the lateral rotation apparatus control signals 158 to the actuator 136 via a communication link 160, to activate or deactivate the actuator 136. For example, the control signals 158 may cause a motor to drive mechanical elements (e.g., linkages 122, 124, 126, 128, 130, 132, 134) to rotate a support section 116, 118, 120, or may cause an air supply to increase or decrease a supply of air to one or more of the bladders 116, 118, 120 in response to the lateral rotation apparatus control signals 158. For example, the control signals 158 may cause one or more of the actuator(s) 136 to turn on or off, increase or decrease a power level, or supply positive or negative pressure to one or more of the support sections or bladders 116, 118, 120. Features of the multi-occupant control module 164 and the supine position control module 166 are described in more detail below, with reference to FIGS. 5 and 6,

respectively.

[0024] In FIG. 2, the person support surface 102 is shown in a state in which the lateral rotation apparatus 108 of the support segment 104 is activated to place the person 1 in a nonsupine position on the support segment 104. At the same time, the support segment 106 remains in a flat position, allowing the person 2 to remain in a supine position. The position of the person 1 in FIG. 2 is considered "non-supine" in that while the person 1 is laying on his back, the head, torso, and legs are rotated at different angles, so that the person 1 is not laying flat.

[0025] Relative dimensions of the person support surface 102 are also shown in FIG. 2. The support segment 104 has a width W1, and the support segment 106 has a width W2. The widths W1, W2 may be the same or different. The width W is greater than either the width W1 or the width W2, and may equal the sum of W1 plus W2. The person support surface 102 has a length L, which is greater than either of W1 and W2 and typically greater than the width W. Illustratively, both of the support segments 104, 106 have the same length L, but may have different lengths, in other embodiments. It should be noted that the support segments 104, 106 can be subcomponents of the same support surface (e.g., a double bed, with one mattress having two lateral sides), such that both person 1 and person 2 are on the same surface), or the support segments 104, 106 may be separate surfaces (e.g., two mattresses supported by a common support frame). Each or either of the support segments 104, 106 may be equipped with a lateral rotation apparatus 108. For example, both persons 1 and 2 could be apnea sufferers and thus both sides of the person support surface 102 would be equipped with a lateral rotation apparatus 108. In such embodiments, the operation of both of the lateral rotation apparatuses can be coordinated by the control unit 156.

[0026] In FIG. 3, the person support surface 102 is shown in a configuration in which a lateral rotation apparatus 308 is part of the support segment 106. As such, either or both support segments 104, 106 may be configured with a lateral rotation apparatus 108, 308. As shown in FIG. 3, the lateral rotation apparatus 308 includes support planes 310, 312, 314 and support sections (e.g., foam and/or bladders) 316, 318, 320. The illustrative lateral rotation apparatus 308 is analogous to the lateral rotation apparatus 108. As such the support planes 310, 312, 314 may be embodied in a similar manner as the support planes 110, 112, 114, and the support sections 316, 318, 320 may be embodied in a similar manner as the support sections 116, 118, 120, described above. In other embodiments, the components of the person support surface 102 and more particularly, the lateral rotation apparatus 108, 308, may include other components and/or other configurations of the same components. For instance, portions of the person support surface 102, and more generally the person support system 100, may include one or more of the features shown in FIGS. 7-12 and 13A-13D.

[0027] The illustrative lateral rotation apparatus 108 includes a support surface comprising head, torso and leg segments each having an independently rotatable person support plane 110, 112, 114; and corresponding support sections 116, 118, 120, which support each person support plane. The support sections 116, 118 120 may be embodied as different subsections of a common support surface or as separate support surfaces. Further, the support sections 116, 118, 120 need not be independent from one another. For example, the support sections 116, 118, 120 may share a common layer, with one or more additional layers above or below the support sections 116, 118, 120.

[0028] In some embodiments, the ranges of lateral tilt angles that the support planes 110, 112, 114 can assume are as follows. The actuator 136 may be operable to rotate the support plane 110 (e.g., head segment) to a head tilt angle in the range of about 7 to about 30 degrees relative to a horizontal support plane; and the actuator 136 may be operable to rotate to rotate the support plane 112 (e.g., torso segment) to a torso tilt angle that is within a range of about 5 degrees to about 10 degrees less than the head tilt angle. The support section 118 may be configured to rotate the support plane 112 (e.g., torso segment) to a torso tilt angle in the range of about zero to about 25 degrees. The support section 116 may be configured to rotate the support plane 110 (e.g., head segment) to a head tilt angle in the range of about 10 to about 15 degrees. The support section 118 may be configured to rotate the support plane 112 (e.g., torso segment) to a torso tilt angle in the range of about 5 to about 10 degrees. The support section 120 may be inflatable to rotate the support plane 114 (e.g., leg segment) to a leg tilt angle in the range of about 0 to about 5 degrees. In some embodiments, the lateral rotation apparatus 108 is configured to position/rotate all of the support planes 110, 112, 114 to the same angle (e.g., all of the support planes 110,112, 114 rotated to an angle of about 10 degrees). In some embodiments, the head, torso, and/or leg tilt angles may be computed in order to allow for indentation of the support surface 102 underneath body parts such as shoulders, arms and hips (e.g., so that the patient's shoulder, arm, or hip can rest comfortably underneath the body).

[0029] The control unit 156 (e.g., a bed or mattress controller) may control inflation of the bladder 116 and the bladder 118 to maintain a differential between the head tilt angle and the torso tilt angle that is in the range of about 5 to about 10 degrees. In other words, the control unit 156 may coordinate lateral rotation (e.g., lateral tilt) angle changes of the support planes 110, 112 so that the differential between the two angles does not exceed a desired amount.

[0030] In some embodiments, the support plane 112 (e.g., torso segment) may be longitudinally longer than the support plane 110 (e.g., head segment), and the support plane 114 (e.g., leg segment) may be longitudinally longer than the support plane 112 (e.g., torso segment). For example, the support plane 110 (e.g., head segment) may have a longitudinal length in the range of about 40.6 centimetres (16 inches); the support plane 112 (e.g., the torso segment) may have a longitudinal length in the range of about 61.0 centimetres (24 inches); and the support plane 114 (e.g., the leg segment)

may have a longitudinal length in the range of about 101.6 centimetres (40 inches).

[0031] Portions of the person support surface 102 may be made of a support material that has a density, such as a foam material. The head tilt angle may be configured as a function of the density of the support material. Either or both of the torso tilt angle and the leg tilt angle may also be configured as a function of the density of the support material. In other words, the head, torso and leg tilt angles may vary according to the density of the material used to build the person support surface 102 or person-supporting portions thereof.

[0032] Alternatively or in addition, the head, torso, and leg tilt angles may be configured as a function of an occupant's body weight and/or as a function of the morphology of the person's body interfacing with the person support surface 102. Thus, the occupant's body weight can be an additional input for the calculation of the tilt angle. In addition, a sensor that measures the actual tilt angle of the person's body can be used in a closed-loop system to determine the optimum tilt angles for the support planes 110, 112, 114.

[0033] Referring now to FIG. 4, a simplified block diagram of an embodiment 400 of the person support system 100 is shown. The person support system 400 includes the lateral rotation control unit 156, one or more communication links 426, the air supply 136, the sensors 140, 142, and one or more other devices 428. While the illustrative embodiment 400 is shown as involving multiple components and devices, it should be understood that the person support system 400 may constitute a single device, alone or in combination with other devices. For example, the air supply 136 may be a component of the control unit 156, a component of the person support surface 102, or a separate component. Each or any of the components 156, 140, 142, 428, 136 may be in communication with one another via one or more of the communication links 426.

[0034] In some embodiments, portions of the system 400 may be incorporated into other systems or computer applications. Such applications or systems may include, for example, commercial off the shelf (COTS) or custom-developed devices or systems. As used herein, "module" or "component" may refer to, among other things, any type of computer program or group of computer programs, whether implemented in software, hardware, firmware, or a combination thereof, and includes self-contained, vertical, and/or shrink-wrapped applications, distributed and cloud-based applications, and/or others.

[0035] The illustrative lateral rotation control unit 156 includes at least one processor 410 (e.g. a microprocessor, microcontroller, digital signal processor, etc.), memory 412, and an input/output (I/O) subsystem 414. The control unit 156 may be embodied as any type of computing device capable of performing the functions described herein. Although not specifically shown, it should be understood that the I/O subsystem 414 can include, among other things, an I/O controller, a memory controller, and one or more I/O ports. The processor 410 and the I/O subsystem 414 are communicatively coupled to the memory 412. The memory 412 may be embodied as any type of suitable computer memory device, including fixed and/or removable memory devices (e.g., volatile memory such as a form of random access memory or a combination of random access memory and read-only memory, such as memory cards, e.g., SD cards, memory sticks, hard drives, and/or others).

[0036] The I/O subsystem 414 is communicatively coupled to a number of hardware, firmware, and/or software components, including the multi-occupant control module 164 and the supine position control module 166. The I/O subsystem 414 is also communicatively coupled to one or more data storage devices 418, a communication subsystem 424, and a user interface subsystem 422. The user interface subsystem 422 may include, for example, hardware or software buttons or actuators, a keypad, a display device, visual cue illuminators, and/or others.

[0037] The data storage device 416 is embodied as one or more machine readable storage media and may include one or more hard drives or other suitable data storage devices (e.g., flash memory, memory cards, memory sticks, and/or others). In some embodiments, portions of the system 400 containing data or stored information, e.g., multi-occupant position data 418, supine sleep limit data 420, and/or other data, reside at least temporarily in the data storage device 416. Portions of the system 400, e.g., multi-occupant position data 418, supine sleep limit data 420, and/or other data, may be copied to the memory 412 during operation of the control unit 156, for faster processing or other reasons.

[0038] The communication subsystem 424 communicatively couples the control unit 156 to one or more other devices, systems, or communication networks, e.g., a local area network, wide area network, personal cloud, enterprise cloud, public cloud, and/or the Internet, for example. Accordingly, the communication subsystem 424 may include a databus, datalink, one or more wired or wireless network interface software, firmware, or hardware, for example, as may be needed pursuant to the specifications and/or design of the particular embodiment of the control unit 156. The system 100 may also access data on a personal mobile device, where such data is either stored in the device memory or through its connection to the Internet, cloud, or other communication network. For example, a WIFI-enabled device such as a body weight scale or fitness tracker can send measured body weight data to an app on the mobile device. Such body weight data can be transmitted wirelessly to and used by the control unit 156 to, e.g., calculate the tilt angles of the support planes 110, 112, 114.

[0039] The other device(s) 428 may be embodied as any suitable type of computing device, electronic device, or electromechanical device capable of performing the functions described herein, such as any of the aforementioned types of devices or other electronic devices. For example, in some embodiments, a device 428 may operate a "back end"

portion of the dynamic therapy system 162, by performing data storage or other operations of the control unit 156. In other embodiments, a device 428 may operate a "front end" portion of the dynamic therapy system 162. For instance, a front end portion may be embodied as an "app" that runs on a personal mobile electronic device, which enables user input to the dynamic therapy system 162 and display of output produced by the dynamic therapy system 162.

[0040] The system 400 may include other components, sub-components, and devices not illustrated in FIG. 4 for clarity of the description. In general, the components of the system 40 are communicatively coupled as shown in FIG. 4 by one or more communication links 2048, e.g., signal paths, which may be embodied as any type of wired, optical, or wireless signal paths capable of facilitating communication between the respective devices and components, including direct connections, public and/or private network connections (e.g., Ethernet, Internet, etc.), or a combination thereof, and including short range (e.g.,. Near Field Communication) and longer range (e.g., Wi-Fi or cellular) wireless communication links.

[0041] Referring now to FIG. 5, an example of a method 500 executable by one or more components of the person support system 100 (e.g., by the multi-occupant control module 164 of the control unit 156), is shown. The method 500 may be embodied as computerized programs, routines, logic and/or instructions, which may be embodied in hardware, software, firmware, or a combination thereof, of the system 100 and/or one or more other systems or devices in communication with the system 100. In block 510, the system 100 determines whether a "person 1" (e.g., a person needing apnea therapy or another type of therapy provided by the lateral rotation apparatus 108) is in position for the therapy to begin. To do this, the system 100 reads and analyzes data signals from an occupant sensor monitoring a portion of a person support surface that includes a lateral rotation apparatus (e.g., the support segment 104). The system 100 may compare the sensed data values to known values indicative of various patient positions, which may be determined based on experimentation and test results. In doing so, the system 100 may query a database or access a lookup table (e.g., multi-occupant data 418), and then perform a logical comparison of the current sensed value to one or more known values indicative of a person position relative to the support surface. For instance, the system 100 may determine from force sensor or pressure sensor readings that person 1 is laying down on the therapy-providing support segment. As another example, the system 100 may determine, based on one or more sensor inputs, that a substantial portion of person 1 is not positioned on the therapy-providing support segment. This may occur if person 1 is sitting on the edge of the person support surface or laying partially on the other lateral side of the person support surface (e.g., the support segment 106). The specific parameters for determining whether person 1 is in a therapy enabling position may be selected according to the requirements of a particular design of the system 100. If the system 100 does not detect that person 1 is in a therapy-enabling position, the system 100 remains in block 510. If the system 100 detects that person 1 is in a therapy enabling position, the system 100 proceeds to block 512.

[0042] In block 512, the system 100 determines whether a "person 2" is in a therapy enabling state. The specific parameters for determining whether person 2 is in a therapy enabling state may be selected according to the requirements of a particular design of the system 100. For instance, the therapy enabling state may be defined as a sleep state, e.g., whether the person 2 is fully asleep, or in a REM state of sleep, or not yet asleep, or fully awake, or as an activity state, based on the person 2's level of motor activity in relation to the patient support surface. To determine whether person 2 is in a therapy-enabling state, the system 100 reads and analyzes data signals from an occupant sensor monitoring a portion of a person support surface that supports person 2 (e.g., the sensor 142). The system 100 may compare the sensed data values to known values indicative of various therapy-enabling states, which may be determined based on experimentation and test results. In doing so, the system 100 may query a database or access a lookup table (e.g., supine sleep limit data 420), and then perform a logical comparison of the current sensed value to one or more known values indicative of a desired therapy-enabling state. If the system 100 determines in block 512 that person 2 is not in a therapy-enabling state (e.g., person 2 is not yet asleep), the system 100 proceeds to block 514. If the system 100 determines in block 512 that person 2 is in a therapy enabling state (e.g., person 2 is in a deep sleep and is therefore unlikely to be bothered by the therapy), the system 100 proceeds to block 516.

[0043] In block 514, the system 100 controls the lateral rotation apparatus to a nontherapy state. To do this, the system 100 returns the therapy-providing segment of the person support surface (e.g., the support segment 104) to a non-therapy position (e.g., a flat position), if the segment was, immediately prior to block 512, in a therapy-providing position, or allows the therapy-providing segment to remain in the non-therapy position (if the segment was already in a non-therapy, e.g., flat, position). In other words, the system 100 delays the lateral rotation therapy for person 1 if person 2 is not detected as being in the desired therapy enabling state.

[0044] In block 516, the system 100 controls the lateral rotation apparatus to a therapy state. To do this, the system 100 transitions the therapy-providing segment of the person support surface (e.g., the support segment 104) to a therapy position (e.g., a progressive lateral tilt angle position), if the segment was, immediately prior to block 516, in a non-therapy providing position, or allows the therapy-providing segment to remain in the therapy position (if the segment was already in a therapy, e.g., progressive lateral tilt, position). In other words, the system 100 initiates the lateral rotation therapy for person 1 if person 2 is detected as being in the desired therapy enabling state. Conversely, the system 100 terminates or suspends the lateral rotation therapy if either person 1 or person 2 is not in the desired state. For example,

if person 2 wakes up or is detected as having a restless sleep, the system 100 may suspend the lateral rotation therapy in block 514. Following block 516, the method 500 may conclude or return to block 510. To initiate or suspend lateral rotation therapy, the system 100 activates or deactivates the actuator(s) 136 by an appropriate amount or for an appropriate duration of time, in order to achieve the desired configuration of the person support surface. For example, the system 100 may turn a motor or an air supply on or off, adjust the power level, or adjust other operating parameters of the actuator 136.

[0045] Referring now to FIG. 6, an example of a method 600 executable by one or more components of the person support system 100 (e.g., by the supine position control module 166 of the control unit 156), is shown. The method 600 may be embodied as computerized programs, routines, logic and/or instructions, which may be embodied in hardware, software, firmware, or a combination thereof, of the system 100 and/or one or more other systems or devices in communication with the system 100. In block 610, the system 100 identifies one or more supine position evaluation parameters. The supine position evaluation parameters may be defined or selected according to the requirements of a particular design of the system 100, and may include AHI, occupant position, occupant sleep state, and/or other parameters. In block 612, the system 100 computes or determines data indicative of a maximum supine position duration. As used herein, "maximum supine position duration" may refer to, among other things, a maximum amount of time that a person (e.g., a person needing apnea therapy) should spend in the supine position, in order to minimize the risk of occurrence of an apnea event. To determine the maximum supine position duration, the system 100 may query a database or access a lookup table, or read sensed values from, e.g., sensor 140, to obtain a data value indicating the maximum supine position duration based on demographic criteria or patient-specific criteria (such as the patient's AHI score, sleep state, or sleep position). For instance, a sensor 140 may be used to perform real-time (e.g., continuous) monitoring of AHI values (e.g., both supine and non-supine), and the system 100 can adjust the maximum supine position duration and/or tilt angle in response to changes in the AHI score as detected in real-time. According to the invention, the person's supine AHI and lateral AHI are used alone or in combination to calculate the maximum supine position duration (and optionally other data values used by the control unit 156). In some embodiments, the supine position parameter(s) identified in block 610 may be used to determine or compute the maximum supine position duration in block 612, either statically or dynamically. Following block 612, the illustrative embodiment of system 100 enters a loop 624 in which the system 100 iteratively and dynamically monitors the supine position evaluation parameter(s) and adjusts the lateral rotation apparatus as needed to avoid the occupant's supine position evaluation parameter(s) falling outside an acceptable range (e.g., an AHI score greater than about 5). As such, the system 100 may be configured to dynamically adjust the subject's supine position duration based on his or her current AHI score. According to the invention, the system 100 monitors the length of time that the occupant (e.g., person 1 of FIG. 1) spends in the supine position over time, to prevent the length of time in the supine position exceeding the applicable maximum supine position duration. For instance, in the loop 624, the system 100 may implement a fixed maximum supine position duration and simply track the amount of time the occupant spends in the supine position (e.g., by setting a timer) and compare the detected amount of time to the pre-determined maximum supine position duration value (which may be determined based on testing with a representative sample of subjects using the patient support surface in a number of different surface configurations). The system 100 can change the tilt position durations dynamically as well (e.g., as AHI rates change throughout a night of sleep, the amount of time spent in a tilt position can be dynamically adjusted).

[0046] In the illustrative embodiment, in block 614, the system 100 determines whether the patient/occupant (e.g., person 1) is in the supine position. To do this, the system 100 may read and analyze data signals from an occupant sensor (e.g., sensor 140) and compare the sensed data values to known values indicative of various patient positions. Alternatively or in addition, the system 100 may determine the current state of the lateral rotation apparatus (e.g., by checking to see whether the bladders 116, 118, 120 are inflated or deflated, or by checking the current operational state of the actuator 136, or by checking to see the current rotational angle of the support sections 116, 118, 120, using, e.g., an angle sensor). If the system 100 does not detect that the patient/occupant is in a supine position, the system 100 remains in block 614. If the system 100 detects that the patient/occupant is in the supine position, the system 100 proceeds to block 616.

[0047] In block 616, the system 100 begins monitoring the patient/occupant's supine position evaluation parameter (e.g., AHI, sleep state, or current supine position duration). In block 618, the system 100 determines whether the monitored supine position evaluation parameter indicates that the patient/occupant's supine position duration equals or exceeds the maximum supine position duration. For example, the system 100 may compare the patient/occupant's AHI value to a threshold value or compare the current supine position duration to the maximum supine position duration determined in block 612. Alternatively or in addition, an algorithm may determine the minimum effective tilt angle to reduce AHI to below a threshold value in order to increase compliance by minimizing discomfort caused by a higher tilt angle. The system 100 remains in block 618 if the supine position duration does not exceed the maximum supine position duration value. If the supine position duration equals or exceeds the maximum supine position duration, the system 100 proceeds to block 620.

[0048] In block 620, the system 100 determines or computes the surface angle adjustments needed to transition the

patient/occupant out of the supine position. To do this, the system 100 may query a database or access a lookup table that maps patient characteristics (such as gender, size, body weight, or AHI) to appropriate surface angles, for example.

[0049] In block 622, the system 100 controls the lateral rotation apparatus to make the surface angle adjustments determined or computed in block 620. To do this, the system 100 may activate or deactivate the actuator(s) 136 to rotate one or more of the support sections 116, 118, 120, or inflate or deflate one or more of the bladders 116, 118, 120, by an appropriate amount, to achieve the desired surface angles. It should be noted that the features of the method 600 and more generally, the supine position control module 166, need not be used on a multi-occupant surface. Rather, the features of the method 600 and the supine position control module 166 are applicable to single-person support surfaces, such as those shown in 8-12 and 13A-13D, and can be used in connection with single-person support surfaces in the manner described above. Further, in multi-occupant embodiments, operation of the method 600 and/or the supine position control module 166 may be coordinated with the operation of the multi-occupant control module 164 and method 500. For instance, the method 600 may be initiated as a result of the system 100 determining in block 512 of FIG. 5 that a person 2 is in a therapy-enabling state.

[0050] Referring now to FIGS. 7-8, an adverse event mitigation system 70 is shown. The illustrative adverse event mitigation system 70 is configured to help reduce the likelihood of an adverse event occurring and/or stop an adverse event in progress. In some contemplated embodiments, the adverse event mitigation system 70 may help reduce the likelihood of obstructive sleep apnea occurring and/or may help stop an obstructive apnea event in progress. In other contemplated embodiments, the adverse event mitigation system 70 may help reduce the likelihood of other adverse events occurring and/or stop other adverse events in progress.

[0051] The adverse event mitigation system 70 includes a person support apparatus 72, a person support surface 74 supported on the person support apparatus 72, and a control system 76 as shown in FIG. 7. In some embodiments, the person support apparatus 72 is a hospital bed frame and the person support surface 74 is supported thereon as shown in FIG. 8. In other embodiments, the person support apparatus 72 can be a stretcher, an operating room table, or other person supporting structure (including a consumer-oriented device, such as a lounger or a recliner). The person support apparatus 72 includes a lower frame 87, supports 88 or lift mechanisms 88 coupled to the lower frame 87, and an upper frame 80 movably supported above the lower frame 87 by the supports 88 as shown in FIG. 8. The lift mechanisms 88 are configured to raise and lower the upper frame 80 with respect to the lower frame 87 and move the upper frame 80 between various orientations, such as Trendelenburg and reverse Trendelenburg.

[0052] The upper frame 80 includes an upper frame base 84, a deck 86 coupled to the upper frame base 84, and a plurality of actuators 87 coupled to the upper frame base 84 and the deck 86 as shown in FIG. 8. The plurality of actuators 87 are configured to move at least a portion of the deck 86 along at least one of a longitudinal axis, which extends along the length of the upper frame 80, and a lateral axis, which extends across the width of the upper frame 80, between various articulated configurations with respect to the upper frame base 84.

[0053] The person support surface 74 is configured to support a person thereon and move with the deck 86 between various configurations including a chair position, a horizontal position, and positions intermediate the horizontal and chair positions. In some embodiments, the person support surface 74 is a hospital bed mattress. In other embodiments, the person support surface 74 is a consumer mattress.

[0054] In some embodiments, one or more articulating sections of the deck 86 help move and/or maintain the various portions of the person support surface 74 at different lateral rotation angles (such as the angles α, β and γ shown in the embodiment of FIG. 12) with respect to the reference plane RP1. In the illustrative embodiments, the person support surface 74 is a powered (e.g., dynamic) surface configured to receive fluid (e.g., air) from a fluid supply (e.g., the air supply 136). The person support surface 74 has a mattress core that can be composed of a single type of material or a combination of materials and/or devices. In the illustrative embodiments, the mattress core includes at least one fluid bladder therein that receives fluid from a fluid supply to maintain the fluid pressure within the fluid bladder at a predetermined level. In some embodiments, the powered surface can include non-powered components, such as a foam frame surrounding or supporting one or more fluid bladders.

[0055] In some contemplated embodiments, the mattress core includes dynamically inflatable or static fluid bladders that are configured to support the cervical vertebrae and scapula, respectively, when inflated. The arrangement of the inflatable fluid bladders can vary depending on any number of factors, including, but not limited to, a person's body type and the angle at which the surface is at with respect to the reference plane RP1. In some embodiments, the fluid bladders are configured to laterally tilt the head and/or torso of the occupant. In some embodiments, wedge shaped fluid bladders (not shown) are positioned in head and torso portions of the support surface 74 and are configured to increase the angles of the occupant-contacting surfaces of the head and torso portions, respectively.

[0056] In some embodiments, the head and torso of the occupant can be tilted at different angles. For example, the person support apparatus 72 and/or the person support surface 74 can laterally rotate the occupant so that the torso is at an angle in the range of about 10 degrees to about 15 degrees or more, with respect to the reference plane RP1, and the occupant's head is at a non-supine angle (e.g., an angle of about 180° with respect to the reference plane RP1, or, an angle that is not within a range of about 35 to about 45 degrees of vertical orientation). Rotation of the occupant's

torso can help the occupant maintain his or her head at a non-supine angle (e.g., an angle of about 180° with respect to the reference plane RP1 or an angle that is not within a range of about 35 to about 45 degrees of vertical orientation).

[0057] Portions of the mattress core of the support surface may be composed of a cellular engineered material, such as a single density foam. In some embodiments, the support surface 74 includes multiple zones with different support characteristics configured to, e.g., enhance pressure redistribution as a function of the proportional differences of a person's body. Also, in some embodiments, the mattress core of the support surface 74 includes various layers and/or sections of foam having different impression load deflection (ILD) characteristics, such as may be found in the NP100 Prevention Surface, AccuMax Quantum™ VPC Therapy Surface, and NP200 Wound Surfaces sold by Hill-Rom®.

[0058] Referring now to FIG. 7, the control system 76 is configured to change at least one characteristic of the person support apparatus 72 and/or person support surface 74, e.g., to help reduce the likelihood of an adverse event occurring and/or stop an adverse event in progress. The control system 76 includes a processor 700, an input 702, and memory 704. In some embodiments, the input 702 includes a sensor 706, such as, a position sensor, a pressure sensor, a temperature sensor, an acoustic sensor, and/or a moisture sensor, configured to provide an input signal to the processor 700 indicative of a physiological characteristic of the occupant, such as, the occupant's heart rate, respiration rate, respiration amplitude, skin temperature, weight, and position. In some embodiments, the sensors 706 are incorporated into the person support surface 74 or a topper positioned on the person support surface, for example, as disclosed in U.S. Patent No. 7,515,059 to Price et al. and U.S. Patent Publication No. 2011/0068928 to Riley et al. In some contemplated embodiments, the sensors 706 include, for example, RFID tags, accelerometers, proximity sensors, level sensors, or other physical tracking sensors that may be integrated into or coupled to, for example, ear plugs, ear phones, adhesive sensors, earlobe clips, eye covers, hats, nose strips or other devices that are attached to the patient's head or worn by the patient so that the position/orientation of the patient's head can be tracked. Information captured by monitoring the lateral position of the user's upper respiratory tract has several benefits, including one or more of the following: providing more accurate measurements of the upper respiratory angle for diagnosis of positional obstructive sleep apnea (in one example, sleep labs can use the information to more accurately diagnose POSA); providing biofeedback to help the user to train to maintain a posture that prevents POSA (positional obstructive sleep apnea); tracking performance of the system to determine if the system is achieving a sufficient upper respiratory angle to prevent apnea; monitoring compliance to determine if the system is being used; monitoring the upper respiratory angle and recording the angle when a sleep apnea event occurs; and controlling a surface capable of providing lateral rotation as a function of the inputs from the sensors 706, tracking whether optimal lateral position has been achieved, and controlling the system to achieve a desired head lateral position and/or upper respiratory angle. In some contemplated embodiments, the sensors 706 are tracked by reading devices (i.e., an RFID or radio frequency identification, reader) in a siderail, person support surface, deck, headboard, or location on or in the person support apparatus 70 or person support surface 74, or on or in a headwall in the room or other location in the room. In some contemplated embodiments, the sensor 706 includes a camera positioned at the foot of the bed or above the bed, as disclosed in U.S. Patent Publication No. 2012/0029879 to Sing et al., for example, to track the orientation of the person's head.

[0059] In some embodiments, the input 702 includes a user interface 708 configured to receive information from a caregiver or other user. In other embodiments, the input 702 is an Electronic Medical Record (EMR) system 710 in communication with the processor 700 via a hospital network 712. In some embodiments, the processor 700 can output information, automatically or manually upon caregiver input, to the EMR for charting, which can include therapy initiation and termination, adverse event occurrence information, therapy protocol used, caregiver ID, and any other information associated with the occupant, caregiver, person support apparatus 72, person support surface 74, and an adverse event.

[0060] The memory 704 stores one or more instruction sets configured to be executed by the processor 700. The instruction sets define procedures that, when executed by the processor, cause the processor 700 to implement one or more protocols that modify the configuration of the person support apparatus 72 and/or the person support surface 14. In one illustrative embodiment, the instruction set defines a proactive procedure that causes the processor 700 to configure the person support apparatus 72 and/or the person support surface 74 in response to an input specifying that the occupant is at risk for sleep apnea. A procedure begins when the processor 700 receives an input signal from the input 702 indicative of the level of risk for an apnea event occurring. In some contemplated embodiments, the level of risk is input from a field in the occupant's EMR. In some contemplated embodiments, the level of risk is input by a caregiver through the user interface, which may arise from a doctor's order or be based on a patient scoring system. In some contemplated embodiments, the level of risk is determined based on a risk score that is calculated by the processor 700 based on a number of factors, including, but not limited to, one or more of the factors listed in TABLE 1 below:

TABLE 1. Illustrative Risk Factors.

Predisposing physical characteristics	• BMI in the 95th percentile for age and gender (i.e., 35 kg/m2)

(continued)

	• 43.2 centimetres (17 inches neck) circumference for men (40.6 centimetres (16 inches) for women) • craniofacial abnormalities that affect the airway • anatomical nasal obstructions • tonsils that nearly touch or do touch in the medline
History of apparent airway obstruction during sleep	• loud or frequent snoring • observed pauses in breathing while asleep • awakening from sleep with a choking sensation • frequent arousal from sleep
Somnolence	• frequent somnolence or fatigue despite getting an adequate amount of sleep • falling asleep easily in a nonstimulating place despite adequate sleep
Sleep study results	
Invasiveness of surgery and anesthesia	• superficial under local or peripheral nerve block without sedation • superficial with moderate sedation or general anesthesia
	• peripheral with spinal or epidural anesthesia and no more than moderate sedation • peripheral with general anesthesia • airway surgery with moderate sedation • major surgery with general anesthesia • airway surgery with general anesthesia
Requirement of postoperative opioids	• none • low-dose oral opioids • high-dose oral opioids or neuraxial or parenteral opioids
Estimation of perioperative risk	
Sex and age of occupant	• Estimated sleep disordered breathing is 9% in women and 24% in men with the prevalence for obstructive sleep apnea being 2% in women and 4% in men. The percentages likely increase for older and more obese people

[0061] In some embodiments, the position and/or the orientation of the occupant with respect to patient facing surface of the person support surface 74 is detected and can influence how the person support surface 74 and/or the person support apparatus 72 are configured to move the occupant to the desired position. For example, if the occupant is positioned along the left edge of the patient facing surface of the person support surface 74, the protocol will not rotate them to the left. In some contemplated embodiments, the protocol is terminated because the occupant is in the correct position. In some contemplated embodiments, the protocol helps to maintain the occupant in the position. The position of the occupant on the person support surface 74 can be determined a number of ways, including sensing the force distribution on the upper frame 80 utilizing one or more load cells (not shown) coupled to the upper frame 80, calculating the occupant's center of gravity using the one or more load cells, sensing pressures within the fluid bladders, using a camera (not shown) or 3D sensor (not shown), or using other methods.

[0062] Similar procedures can be used for a number of other adverse conditions. In some contemplated embodiments, a procedure can be used to determine if a person is at risk for or has gastroesophageal reflux disease and select a protocol that assists the occupant in maintaining a left lateral decubitus position or semi-reclining position while sleeping. In some contemplated embodiments, the procedure can be used to determine if a person is at risk for or has chronic respiratory insufficiency and select a protocol for the caregiver to approve that assists the occupant in maintaining a left lateral decubitus position while sleeping. In some contemplated embodiments, the procedure can be used to determine if a person is at risk for of has allergies to, for example, feather or down filled pillows, cushions or covers, and can alert the caregiver so that they can remove the item. In other contemplated embodiments, the above-described described procedure can be used to determine if the person is at risk for or has one or more other conditions, such as, for example, asthma, pregnancy, sleep paralysis or hallucinations, snoring, stroke bruxism, coughing, hypoxaemia in geriatric inpatients, stroke, or tuberculosis, that might be affected negatively by sleeping in the supine position and select a protocol and/or alert the caregiver so that the person support apparatus 72 and/or the person support surface 74 can be configured to maintain the occupant in a desirable position. In some contemplated embodiments, the procedure can be used to

change the sleeping position of occupants to help stimulate blood oxygenation, which can undesirably decrease as the occupant remains stationary. Some patients may have a contraindication to be laterally tilted to one side but not the other, and thus rotation will only tilt to the non-contraindicated side. For example, a recent orthopedic procedure on an arm may induce pain when lying on that side, or a collapsed lung may cause pain on one side. Data indicative of these and other types of patient-specific health conditions may be input by a caregiver (e.g., by a user interface of the control unit 156) or by a communications interface with, e.g., an electronic medical records (EMR) system.

[0063] Referring now to FIGS. 9-12, a support system 1100 suitable for supporting a user, such as a person, for example, includes plurality of support pieces, namely a first or leg support piece 1102 forming a first support plane 1104, a second or torso support piece 1106 forming a second support plane 1108, and a third or head support piece 1110 forming a third support plane 1112 that collectively define a segmented, multi-plane, laterally angled sleep surface 1114 having progressively greater angles of rotation along a longitudinal axis 1115 of support system 1100, from a first or bottom edge 1116 of sleep surface 1114 to an opposing second or top edge 1118 of sleep surface 1114, resulting in relatively greater rotation of the upper respiratory tract of the user (as necessary for efficacy in preventing obstructive apnea) and relatively lesser rotation in the lower body of the user (resulting in greater comfort and perceived stability by avoiding rotation of a majority of the user's body mass). In alternative embodiments, sleep surface 1114 is formed using any suitable number of support pieces defining corresponding support planes, for example, one support piece forming a smooth contour over a length of sleep surface 1114 from first edge 1116 to opposing second edge 1118 or a plurality of support pieces, such as two support pieces, three support pieces, or more than three support pieces forming a smooth contour over the length of sleep surface 1114.

[0064] Unlike conventional positional therapies for the prevention of obstructive sleep apnea, which attempt to manipulate the user's sleep position and/or orientation using rotation of one plane, in certain embodiments the system described herein uses multiple support planes formed by one or more support pieces to laterally rotate the user. For example, in one embodiment, two support pieces provide two separate support planes, with a first support plane defined by the first support piece configured to support the torso and the legs of the user, and a second support plane defined by the second support piece configured to support the neck and the head of the user. In an alternative embodiment, three support pieces provide three separate support planes, with a first support plane defined by the first support piece configured to support the legs of the user, a second support plane defined by the second support piece configured to support the torso of the user, and a third support plane defined by the third support piece configured to support the head of the user.

[0065] In a further alternative embodiment, more than three support pieces, for example, numerous independent support pieces having a length in a longitudinal direction of sleep surface 1114 of 5.1-45.7 centimetres (2-18 inches) or, more specifically, 10.2-30.5 centimetres (4-12 inches), or, even more specifically, 15.2 centimetres (6 inches), provide a corresponding number of separate support planes. Each support piece can be laterally rotated independently of other support pieces to collectively form sleep surface 1114. In a particular embodiment, the numerous support pieces can be combined to form separate support pieces, for example, creating a first support piece having a length of 45.7 centimetres (18 inches) in the longitudinal direction at the foot of the support system 1100, an adjacent second support piece having a length of 30.5 centimetres (12 inches) in the longitudinal direction, and a third support piece adjacent the second support piece having a length in the longitudinal direction of 15.2 centimetres (6 inches). In these embodiments, the support pieces forming the support planes can be rotated as necessary or desired to achieve an optimal configuration that is clinically effective (i.e., prevents apnea) and demonstrates acceptable tolerance (i.e., allows the user to sleep comfortably). In an alternative embodiment, a continuously sloped sleep surface is formed by a plurality of support pieces without step increases in lateral rotational angle; this is illustrated as a sleep surface with an infinite number of support pieces.

[0066] In the embodiments described herein, the length in the longitudinal direction of each support piece and defined support plane (and the resulting location of transitions between support planes) is designed to achieve clinical efficacy and tolerability. Therefore, a specific length can be defined in a number of configurations, including without limitations: (a) generic plane dimensions (e.g., based on average body geometry, a length of a torso section of the user defined so that when an average user's head is supported by a head support piece, a transition between the torso support piece and the leg support piece occurs below the user's S3 vertebrae); (b) customized plane dimensions (e.g., a torso support plane has a suitable length in the longitudinal direction appropriate to the user's leg length, torso length, and/or a distance from the user's shoulder to his/her inseam); or (c) dynamic plane dimensions (e.g., transitions selected on dynamic surface appropriate to user, selection being either user-selected, care-giver defined, or automatically calculated).

[0067] In certain embodiments, each support piece defining the corresponding support planes is independently rotatable about an axis extending parallel with a longitudinal axis of the support system. The independent rotation of each support piece allows the caregiver or the user the ability to focus on progressively increasing an angle of rotation in one or more support pieces having support planes positioned to support the torso of the user, and the neck and/or the head of the user. In certain embodiments, an angle of rotation (or lateral rotational angle) at which the one or more support planes defined by the support pieces configured to support the neck and/or the head of the user is positioned is greater

than a rotational angle of the one or more support planes defined by the support pieces configured to support the torso of the user, which is greater than a rotational angle at which the one or more support planes defined by the support pieces configured to support the legs of the user is positioned.

[0068] In a particular embodiment, the support plane defined by the support piece configured to support the legs and the torso of the user is positioned at a rotational angle of 10° with respect to a base surface of the support piece, while the support plane defined by the support piece configured to support the head of the user is positioned at a rotational angle of 20° with respect to a base surface of the support piece. In an alternative embodiment, a first support plane defined by the support piece configured to support the legs of the user is positioned at a rotational angle of 10° with respect to a base surface of the first support piece, a second support plane defined by a second support piece configured to support the torso of the user is positioned at a rotational angle of 15° with respect to a base surface of the second support piece, and a third support plane defined by the third support piece configured to support the head of the user is positioned at a rotational angle of 20° with respect to a base surface of the third support piece. In alternative embodiments, the support planes can be positioned at any suitable rotational angle including any suitable lateral rotational angle and/or any suitable longitudinal rotational angle.

[0069] Referring further to FIGS. 9-12, in a particular embodiment, first support piece 1102 defines support plane 1104 positioned at a lateral rotational angle α of 20° to 30°, or more specifically, 20° to 25°, or, even more specifically, 25° with respect to a base surface 1122 of first support piece 1102. Second support piece 1106 defines support plane 1108 positioned at a lateral rotational angle β of 10° to 20°, or more specifically, 10° to 15°, or, even more specifically, 15°, with respect to a base surface 1124 of second support piece 1106. Third support piece 1110 defines support plane 1112 positioned at a lateral rotational angle γ of 5° to 15°, or more specifically, 10°, with respect to a base surface 1126 of third support piece 1106. Other lateral rotational angles and step increases in lateral rotational angles between each support piece may also be used to achieve a progressive lateral rotational angle.

[0070] In some embodiments, each of support pieces 1102, 1106, 1110 are rotatable about longitudinal axis 1115 to provide sleep surface 1114 having a right side slope or, alternatively, a left side slope to allow the user to sleep on his/her right side or left side, respectively. In one embodiment, one or more cylindrical or tubular sections are positioned within at least a portion of first support piece 1102, second support piece 1106, and third support piece 1110 and coaxially aligned with longitudinal axis 1115 to allow each support piece 1102, 1106, 1110 to rotate about longitudinal axis 1115 independently of the other support pieces 1102, 1106, 1110.

[0071] In certain embodiments, support pieces 1102, 1106, 1110 are formed of more than one material, for example, two or more materials, such as two foam materials, having different densities, with the less dense material covering the denser material. In this embodiment, the less dense material is laid on the denser material at the respective base surface and the respective support plane of the support piece to allow sleep surface 1114 to function properly, whether with a right side slope or a left side slope. With the denser material sandwiched between the less dense material, the user will be positioned on the less dense material in either the first or the second orientation.

[0072] In this embodiment, support system 1100 allows the user to sleep on either his/her right side or left side, based on the user's sleeping preference. This sleeping preference may not be static. For example, if the user has an injury, an ache, or a desire to change his/her sleeping preference, the orientation of sleep surface 1114 can be changed at any time to accommodate the user's sleeping preference. The orientation can be changed from day to day or during the night. Moreover, from a manufacturing standpoint, a versatile support system 1100 prevents having to manufacture and distribute a sleep surface 1114 having a right side slope and a separate sleep surface 1114 having a left side slope, which would increase production and distribution costs. Finally, a potential purchaser would not have to commit to a sleep side before purchasing the product, which might be a deterrent to purchasing the product.

[0073] In some embodiments, each support piece 1102, 1106, 1110 includes one or more inflatable fluid bladders configured to contain a fluid, such as air. In this embodiment, a length of each support piece 1102, 1106, 1110 is adjustable by adding fluid or removing fluid from one or more respective fluid bladders. By adding fluid to one or more of the respective fluid bladders, the length of the respective support piece 1102, 1106, 1110 is increased and the length of the respective support plane 1104, 1108, 1112 is also increased. Conversely, removing fluid from one or more of the respective fluid bladders, the length of the respective support piece 1102, 1106, 1110 is decreased and the length of the respective support plane 1104, 1108, 1112 is also decreased. The amount of fluid within the respective fluid bladders can be monitored and controlled electronically or by the user or caregiver using a suitable device including, without limitation, a suitable pneumatic pump or nozzle. In certain embodiments, a coupler, such as one or more snaps or straps, are utilized to maintain the desired amount of fluid within the respective fluid bladders and provide additional support to the respective support plane(s), for example, when the fluid bladders are not inflated.

[0074] As described herein, sleep surface 1114 is customizable to anthropometric dimensions of the individual user to facilitate support system 1100 performance that optimizes or matches the design intent - the body position of the user will prevent or limit undesirable sleep apnea episodes and provide improved comfort.

[0075] The fluid bladders are inflatable with air or another suitable fluid (which can be drained as desired from within the cavities of the fluid bladders into a reservoir). A fluid supply can be positioned at or near support system 1100, such

as on the floor, beneath the bed, or coupled to the bed. The fluid supply is in independent fluid communication with each pair of fluid bladders by an air system to supply a desired amount of fluid to each fluid bladder based on a signal from a control, for example.

[0076] Referring now to FIGS. 13A-13D, there are shown views of a mattress 900 according to another illustrative embodiment of the present disclosure. In this embodiment, the mattress 900 comprises a base 902 which supports a head section 904, a torso section 906, a leg section 908, and a bolster 909. The mattress 900 has a longitudinal length *l* and a lateral width *w*. A central longitudinal axis, or centerline, *a1* runs through the middle of the mattress 900 longitudinally from end to end and a central lateral axis a2 runs through the mattress laterally from side to side. In this embodiment, the mattress 900 is made of polyurethane foam, although the mattress could be made from many other foam (including memory foam or closed cell foam), cloth, and/or fabric materials, and/or structural elements such as springs and air bladders. For example, a viscoelastic foam with an ILD (indention load deflection) rating of about 50 could be used when the angle *Ø1* (described below) is from about 25 to about 30 degrees. Depending on the stiffness (ILD) of the material, the angles disclosed herein can be adjusted somewhat. Smaller angles maybe used when a higher ILD (stiffer) material is utilized, and vice versa. In some embodiments, the material comprises foam having an ILD of from about 25 to about 275.

[0077] The mattress 900 in this embodiment is coated with three coats of F-874 Muraculon vinyl based coating, and one coat of F-894 Muraculon vinyl based coating. Other coverings can be utilized, including those which preserve the density or durability of the foam, or increase its infection control or antimicrobial properties. In some embodiments, no coatings or coverings could be utilized.

[0078] FIG. 13B is a top view of the illustrative embodiment of FIG. 13A looking in the direction labelled 13B in FIG. 13A. As seen in this view, the head section 904 includes a flat top surface 903 and an angled top surface 905 which slants in the lateral direction at an angle relative to the lateral axis a2. The bolster 909 includes a flat top surface 907 and an angled top surface 911 which slants in the longitudinal direction at an angle relative to the longitudinal axis a1. As seen in FIG. 13B, in this embodiment, the bolster 909 extends along the leg section 908 and a portion of the torso section 906, but not along the head section 904. As shown in FIGS. 13A and 13B, a ramping or tapering down of the bolster 909 occurs about midway along the torso section 906 (below the location where the elbow would typically be supported). Accordingly, when this embodiment is used as intended, the head of the patient will typically not migrate adjacent the bolster 909 and will turn sideways at an angle, with a cheek supported by the angled top surface 903, thereby supporting the head at an angle relative to the lateral axis *a2.*

[0079] FIG. 13C is a longitudinal side view (viewed along the longer side) of the illustrative embodiment of FIG. 13A, looking in the direction labelled 13C in FIG. 13B. FIG. 13D is a lateral side view (viewed along the shorter side, or end) of the illustrative embodiment of FIG. 13A, looking in the direction labelled 13D in FIG. 13C. As best seen in FIGS. 13A and 13D, each of the head section 904, torso section 906, and leg section 908 includes an angled top support surface in this embodiment. In particular, the head section 904 includes the angled top surface 905 which slants in the lateral direction, the torso section 906 includes an angled top surface 915 which slants in the lateral direction, and the leg section includes an angled top surface 917 which slants in the lateral direction. The top surface 905 of the head section 904 is intended to support at least a portion of a person's head, and is generally tilted in the lateral direction at a first angle relative the lateral axis a2. The top surface 915 of the torso section 906 is intended to support at least a portion of a person's torso, and is generally tilted in the lateral direction at a second angle relative to the lateral axis a2. The top surface 917 of the leg section 908 is intended to support at least a portion of a person's leg, and is generally tilted in the lateral direction at a third angle relative to the lateral axis a2. In this embodiment, the top surface 905 of the head section 904 is at an angle *Ø1* of about 25 degrees, the top surface 915 of the torso section is at an angle *Ø2* of about 17.5 degrees, and the top surface 917 of the leg section is at an angle *Ø3* of about 10 degrees. In some embodiments, the angle *Ø1* is from about 10 to about 30 degrees, and the angle *Ø2* is from about 0 to about 25 degrees (such as from about 1 to about 20 degrees). In some embodiments, angle *Ø1* is at least about 10 degrees, and in some embodiments is at least about 15 degrees. In some embodiments angle *Ø1* is at least 20 degrees, such as from about 20 to about 25 degrees, and the angle *Ø2* is at least about 10 degrees, such as from about 10 to about 25 degrees.

In some embodiments, the angle *Ø2* is from about 5 to about 15 degrees less than the angle *Ø1*. In some embodiments, the angle *Ø2* is from about 5 to about 10 degrees less than the angle *Ø1*, and in some embodiments the angle *Ø2* is about 7.5 degrees less than the angle *Ø1*. In some embodiments, the angle *Ø2* is from about 15 to about 17.5 degrees. In some embodiments where the head section angle *Ø1* is at about 30 degrees, the angle *Ø2* is at about 15 to about 22.5 degrees. In some embodiments, such gradual turning by having angle *Ø2* be somewhat less than angle *Ø1*, and somewhat more horizontal, has been found to increase comfort while still promoting a good sleeping position and urging the head turn significantly away from the vertical up direction (e.g., 35 degrees or more in both directions, clockwise and counterclockwise from vertical up, regardless of sleeping position.)

[0080] In some embodiments, the angle *Ø3* is from about 0 degrees to about 15 degrees. In some embodiments, the angle *Ø3* is from about 0 degrees to about 12.5 degrees, and in some embodiments is about 10 degrees. In some embodiments, the angle *Ø3* is from about 0 to about 15 degrees less than the angle *Ø2.* In some embodiments, the angle *Ø3* is from about 5 to about 10 degrees less than the angle *Ø2*, and in some embodiments the angle *Ø3* is about

7.5 degrees less than the angle *Ø2*.

[0081] Because the base 902 is flat in this embodiment, on both its top and bottom, these angles *Ø1*, *Ø2,* and *Ø3* are likewise relative to the base and to the underside of the mattress in this embodiment. In some embodiments, the top surfaces 905, 915, and 917 can be curved or nonlinear or otherwise follow a non-straight or smooth path in the longitudinal and/or lateral directions. In such cases, where these angles are nonlinear in the lateral direction, the angle *Ø1* of general lateral sloping of the top surface 905 of the head section can be defined by the angle of a line connecting a point defining the lateral start of the head support surface to a point defining its lateral end (laterally directly across, left to right), or a point at the approximate middle of the support surface (or by averaging the angles of all, or a plurality, of such lines, taken along the section). Likewise, the angle *Ø2* of general sloping of the top surface 915 of the torso section can be defined by the line connecting the point defining the lateral start of the torso support surface to the point defining its lateral end, or a point at the approximate middle of the support surface (or by averaging the angles of all or a plurality of such lines taken along the section). Furthermore, the angle *Ø3* of general sloping of the top surface 917 of the leg section can be defined by the line connecting the point defining the lateral start of the leg support surface to the point defining its lateral end, or a point at the approximate middle of the support surface (or by averaging the angles of all or a plurality of such lines taken along the section).

[0082] In this embodiment of FIGS. 13A-D, the head support surface 905 is sized to support a person's head, the torso support surface 915 is sized to support a person's torso, and the leg support surface 917 is sized to support a person's legs. In some embodiments, the head section 904 is from about 12.7 centimetres (5 inches) to about 76.2 centimetres (30 inches) in length (such as from about 38.1 centimetres (15 inches) to about 63.5 centimetres (25 inches), or at about 50.8 centimetres (20 inches) for example), the torso section 906 is from about 38.1 centimetres (15 inches) to about 127 centimetres (50 inches) in length (such as from about 50.8 centimetres (20 inches) to about 88.9 centimetres (35 inches), or at about 61.0 centimetres (24 inches) for example), and the leg section is from about 63.5 centimetres (25 inches) to about 127 centimetres (50 inches) in length (such as from about 76.2 centimetres (30 inches) to about 101.6 centimetres (40 inches), or about 88.9 centimetres (35 inches) for example).

[0083] Referring now to FIG. 14, support system 1100 includes a suitable computer implemented control system 1190 operatively coupled to the air system. The computer implemented control system includes a computer 1192 having one or more processors 1194 and one or more sleep sensors 1196, such as one or more pressure sensors, coupled in signal communication with processors 1194. Sleep sensors 1196 are configured to monitor the user's sleep patterns and transmit signals indicative of the sensed sleep patterns to processors 1194 for manipulation and evaluation of the data. Based at least in part on the one or more signals received from one or more sleep sensors 1196, control system 1190 is configured to inflate or deflate select fluid bladders to reposition the user during sleep to prevent or limit the occurrence of a sleep apnea episode, for example.

[0084] Additionally, in certain embodiments, the air system is configured to rest on a conventional mattress or may be configured or reinforced to rest directly on a support structure, such as a bed frame or a floor. With the fluid substantially removed from each of the fluid bladders, the air system can be folded or rolled into a compact configuration to facilitate storing and transporting the air system. In certain embodiments, the air system is less expensive than a conventional mattress and more compact to facilitate portability of support system 1100. Additionally, air system as configured prevents or limits disturbance to the user's partner sleeping next to the user.

[0085] The illustrative support system 1100 is a dynamic support system, rather than a static support system, that is configured to control the configuration of sleep surface 1114 based at least in part on data entered into control system 1190 using computer 1192, or another control operatively coupled to computer 1192, and/or sensed by one or more sleep sensors 1196, for example, to improve the performance of sleep surface 1114 in terms of clinical efficacy and user tolerability.

[0086] As described herein and shown schematically, for example, in FIGS. 14 and 15, dynamic support system 1100 includes, in addition to other components, a plurality of sleep sensors 1196 configured to sense and monitor various activities including without limitation, the user's body position, a location of the user with respect to sleep surface 1114, an orientation, for example, a left side orientation or a rights side sleep orientation, of the user, the user's vital signs including his/her sleep state, and additional relevant user activity during sleep. Each sleep sensor 1196 is in signal communication with one or more processors 1194 contained within computer 1192 and configured to gather relevant data and generate and transmit to processors 1194 signals indicative of the data gathered. Sleep sensors 1196 are also configured to receive operation control signals from processors 1194.

[0087] Within computer 1192, data received from sleep sensors 1196 is analyzed and operational control signals are transmitted to sleep sensors 1196 as well as to other components of support system 1100, such as to fluid supply 1188 to activate fluid supply 1188 to provide air to one or more fluid bladders and/or remove air from one or more fluid bladders to adjust sleep surface 1114 based on signals generated by sleep sensors 1196 and analyzed within computer 1192. In one embodiment, computer 1192 includes suitable memory 1198 to store data sensed and/or generated by control system 1190.

[0088] An exemplary method 1200 utilizing control system 1190 for monitoring the sleep activities of a user positioned

on support system 1100 is illustrated in FIG. 15. As described above, control system 1190 includes one or more processors 1194 configured to perform the steps as described herein.

[0089] Control system 1190 is activated 1202 either manually or automatically to monitor the user's sleep activities and patterns as user begins to sleep. In one embodiment, control system 1190 detects when the user begins to fall asleep 1204 and activates support system 1100 (or a dynamic sleep surface) on a delay 1206 to rotate the user at a suitable time after sleep is detected, such as after the user has been asleep for 30 minutes. In an alternative embodiment, control system 1190 is programmed to activate support system 1100 at a preset time, for example, at a 30 minute delay, without relying on monitoring the user's sleep activity. In a particular embodiment, control system 1190 delays inter-sleep rotation of the user until the user is in a deep sleep. Further, when control system 1190 detects that the user is waking, control system 1190 will activate support system 1100 to move sleep surface 1114 to an initial configuration such that the user can exit from support system 1100. In a further embodiment, control system 1190 prevents activation of support system 1100 if control system 1190 detects the user is sleeping in a lateral decubitus position.

[0090] Prior to sleep, the user is able to input 1208 to control system 1190 sleep data 1210 including without limitation, preferred sleeping sides and positions, the user's measurements including, for example, the user's height, weight, and inseam and torso measurements, preferred lateral rotational angles and/or longitudinal rotational angles of one or more support planes defining sleep surface 1114. Based at least in part on the user's input data, control system 1190 is configured to activate support system 1100 to adjust a direction and/or a level of rotation of one or more support planes defining sleep surface 1114. For example, if the user prefers a left side slope to sleep surface 1144, control system 1114 activates fluid bladders within support system 1100 to form the desired lateral left side slope, or if the user's partner is sleeping on the left side of the user, a left angle may be created. In one embodiment, minimal adjustments are made to sleep surface 1114 to maintain the user's AHI under 5 and/or prevent snoring because apneas events and snoring may or may not be equivalent, depending on the user. Additionally, control system 1190 is configured to collected and record data obtained as the user sleeps to diagnose any undesirable or abnormal sleep activities or conditions, including the user's apnea-hypopnea index (AHI), for example.

[0091] During sleep, control system 1190 assesses the user's comfort level 1214 and, in a particular embodiment, compares the current evaluation with previous evaluations. The user's body is then mapped 1216 to map body region locations 1218, and user activities and movements 1220 during sleep. The collected data is then analyzed 1222 to determine: the location of joints including, for example, the user's neck, hips, and knees; preferred surface orientation (right side vs. left side orientation); and body orientation (e.g., mapping pressures at various locations on sleep surface 1114 as a result of the user's body orientation, for example, a lateral sleep position indicated by a narrow pressure mapping profile). In one embodiment, location of one or more support planes are calculated and located based on transition points. Under the pressure mapping, specific pressure points are identified to increase or decrease pressure. For example, select fluid bladders are inflated or deflated based on body location and desired lateral rotational angles.

[0092] Control system 1190 then assesses 1224 the user's body orientation including, for example a determination of head angle 1226 and chest angle 1228. During sleep, control systems also actively monitors 1230 the user's vital signs, which includes measuring and monitoring the user's respiratory rate and amplitude, AHI, sleep state, snoring, and oxygen saturation (SpO_2), for example. If an adverse event is detected, control system 1190 activates 1234 one or more components of support system 1100 to respond appropriately. For example, fluid supply 1188 may be activated to inflate or deflate one or more fluid bladders. Control system 1190 may activate fluid supply 1188 based on one or more of the following events: detection of snoring, detection of an AHI episode (apnea and/or hypopnea), and detection that the user is in a supine position (e.g., supine torso, upper respiratory tract (URT) within 45° of vertical). Control system 1190 may also activate support system 1100 to vibrate to wake the user should control system 1190 detect an adverse event, such as an apnea episode. However, it is not necessary to fully awaken the patient to disrupt apnea episodes; thus, the vibration can be adjusted to the minimal level needed in order to disrupt the apnea event (and thus minimize patient awakenings).

[0093] While certain features have been described in the context of certain illustrative embodiments and examples, it should be understood that such features may be adopted or applied to any of the disclosed embodiments and examples, or to other embodiments and examples.

[0094] Portions of the above embodiments may be described in terms of functional block components and various processing steps. Such functional blocks may be realized by any number of hardware and/or software components configured to perform the specified functions. For example, embodiments may employ various integrated circuit components, e.g., memory elements, processing elements, logic elements, look-up tables, and the like, which may carry out a variety of functions under the control of one or more processors, microprocessors or other control devices. Similarly, where the elements of the above embodiments are implemented using software programming or software elements the embodiments may be implemented with any programming or scripting language such as C, C++, Java, assembler, or the like, with the various algorithms being implemented with any combination of data structures, objects, processes, routines or other programming elements. Furthermore, the embodiments can employ any number of conventional techniques for electronics configuration, signal processing and/or control, data processing and the like. Words such as

mechanism may be used broadly and are not limited to mechanical or physical embodiments, but can include software routines in conjunction with processors, etc.

[0095] The particular implementations shown and described herein are illustrative examples. For the sake of brevity, conventional electronics, control systems, software development and other functional aspects of the systems (and components of the individual operating components of the systems) may not be described in detail. Furthermore, the connecting lines, or connectors shown in the various figures presented are intended to represent exemplary functional relationships and/or physical or logical couplings between the various elements. It should be noted that many alternative or additional functional relationships, physical connections or logical connections may be present in a practical device. Numerous modifications and adaptations will be readily apparent to those skilled in this art.

[0096] The order of execution or performance of the operations in embodiments illustrated and described herein is not essential, unless otherwise specified. That is, the operations may be performed in any order, unless otherwise specified, and embodiments as described may include additional or fewer operations than those disclosed herein.

[0097] Aspects of the disclosure may be implemented with computer-executable instructions. The computer-executable instructions may be organized into one or more computer-executable components or modules (e.g., hardware, software, firmware, or a combination thereof). Aspects of the disclosure may be implemented with any number and organization of such components or modules. For example, aspects of the disclosure are not limited to the specific computer-executable instructions or the specific components or modules illustrated in the figures and/or described herein. Other embodiments may include different computer executable instructions or components having more or less functionality than illustrated and described herein.

Claims

1. A dynamic person support system (100, 400, 1100), comprising:

a person support surface (102);
a lateral rotation apparatus (108, 308) coupled to the person support surface (102), the lateral rotation apparatus (108, 308) comprising a plurality of independently rotatable longitudinally arranged support planes (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) and a lateral rotation actuator (136) operably coupled to one or more of the support planes (110, 112, 114, 310, 312, 314, 1104, 1108, 1112);
a control unit (156) comprising a processor (410) and a non-transitory machine readable storage medium comprising a dynamic therapy routine, the dynamic therapy routine comprising instructions executable by the processor (410) to cause the control unit (156) to control the operation of the lateral rotation apparatus (108, 308) by:

determining a maximum supine position duration;
monitoring the actual supine position duration of a human subject positioned on the person support apparatus; and
controlling the lateral rotation actuator (136) to maintain the actual supine position duration below the maximum supine position duration,

wherein the control unit (156) is configured to compute the maximum supine position duration based on a first apnea-hypopnea index (AHI) value and a second AHI value, wherein the first AHI value is determined while the human subject is in a supine position and the second AHI value is determined while the human subject is in a non-supine position.

2. The dynamic person support system (100, 400, 1100) of claim 1, wherein the lateral rotation actuator (136) comprises an electromechanical device configured to drive lateral rotation of the independently rotatable support planes (110, 112, 114, 310, 312, 314, 1104, 1108, 1112).

3. The dynamic person support system (100, 400, 1100) of claim 1 or claim 2, wherein the lateral rotation actuator (136) comprises a plurality of inflatable bladders (116, 118, 120) supporting the independently rotatable support planes (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) and an air supply operably coupled to the inflatable bladders (116, 118, 120).

4. The dynamic person support system (100, 400, 1100) of any of preceding claim, comprising a sensor in communication with the control unit (156), wherein the control unit (156) is configured to receive a sensed value from the sensor and determine the maximum supine position duration based on the sensed value.

5. The dynamic person support system (100, 400, 1100) of claim 4, wherein the sensed value is indicative of an apnea-hypopnea index (AHI) of the monitored human subject.

6. The dynamic person support system (100, 400, 1100) of claim 4, wherein the sensed value is indicative of a sleep state of the monitored human subject.

7. The dynamic person support system (100, 400, 1100) of claim 5, wherein the control unit (156) is configured to adjust the maximum supine position duration in response to the sensed value.

8. The dynamic person support system (100, 400, 1100) of claim 7, wherein the control unit (156) is configured to increase the maximum supine position duration in response to the sensed value being below a threshold value.

9. The dynamic person support system (100, 400, 1100) of claim 8, wherein the control unit (156) is configured to decrease the maximum supine position duration in response to the sensed value being above a second threshold value.

Patentansprüche

1. Dynamisches Personenauflagesystem (100, 400, 1100), umfassend:

eine Personenauflagefläche (102);
eine Lateraldrehungsvorrichtung (108, 308), die mit der Personenauflagefläche (102) gekoppelt ist, wobei die Lateraldrehungsvorrichtung (108, 308) eine Vielzahl von unabhängig drehbaren in Längsrichtung angeordneten Auflageebenen (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) und ein Lateraldrehungsstellglied (136), das funktionell mit einer oder mehreren der Auflageebenen (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) gekoppelt ist, umfasst;
eine Steuereinheit (156), umfassend einen Prozessor (410) und ein nichtflüchtiges maschinenlesbares Speichermedium, das eine dynamische Therapieroutine umfasst, wobei die dynamische Therapieroutine Anweisungen umfasst, die durch den Prozessor (410) ausführbar sind, um die Steuereinheit (156) zum Steuern des Betriebs der Lateraldrehungsvorrichtung (108, 308) durch Folgendes zu veranlassen:

Bestimmen einer maximalen Dauer der Rückenlage;
Überwachen der tatsächlichen Dauer der Rückenlage eines auf der Personenauflagevorrichtung positionierten menschlichen Subjekts; und
Steuern des Lateraldrehungsstellglieds (136), um die tatsächliche Dauer der Rückenlage unter der maximalen Dauer der Rückenlage zu halten,

wobei die Steuereinheit (156) zum Berechnen der maximalen Dauer der Rückenlage auf Basis eines ersten Apnoe-Hypopnoe-Index- (AHI) -Werts und eines zweiten AHI-Werts konfiguriert ist, wobei der erste AHI-Wert bestimmt wird, während das menschliche Subjekt in einer Rückenlage ist, und der zweite AHI-Wert bestimmt wird, während das menschliche Subjekt in einer Nicht-Rückenlage ist.

2. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 1, wobei das Lateraldrehungsstellglied (136) eine elektromechanische Vorrichtung umfasst, die zum Antreiben der lateralen Drehung der unabhängig drehbaren Auflageebenen (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) konfiguriert ist.

3. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 1 oder Anspruch 2, wobei das Lateraldrehungsstellglied (136) eine Vielzahl von aufblasbaren Blasen (116, 118, 120) umfasst, die die unabhängig drehbaren Auflageebenen (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) stützen, und eine Luftversorgung, die funktionell mit den aufblasbaren Blasen gekoppelt ist, umfasst.

4. Dynamisches Personenauflagesystem (100, 400, 1100) nach einem der vorhergehenden Ansprüche, das einen mit der Steuereinheit (156) in Kommunikation stehenden Sensor umfasst, wobei die Steuereinheit (156) zum Empfangen eines erfassten Werts von dem Sensor und zum Bestimmen der maximalen Dauer der Rückenlage auf Basis des erfassten Werts konfiguriert ist.

5. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 4, wobei der erfasste Wert für einen Apnoe-

Hypopnoe-Index (AHI) des überwachten menschlichen Subjekts bezeichnend ist.

6. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 4, wobei der erfasste Wert für einen Schlafzustand des überwachten menschlichen Subjekts bezeichnend ist.

7. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 5, wobei die Steuereinheit (156) zum Einstellen der maximalen Dauer der Rückenlage als Reaktion auf den erfassten Wert konfiguriert ist.

8. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 7, wobei die Steuereinheit (156) zum Erhöhen der maximalen Dauer der Rückenlage als Reaktion darauf, dass der erfasste Wert unter einem Schwellenwert liegt, konfiguriert ist.

9. Dynamisches Personenauflagesystem (100, 400, 1100) nach Anspruch 8, wobei die Steuereinheit (156) zum Verringern der maximalen Dauer der Rückenlage als Reaktion darauf, dass der erfasste Wert über einem zweiten Schwellenwert liegt, konfiguriert ist.

Revendications

1. Système dynamique de support de personne (100, 400, 1100), comprenant :

une surface de support de personne (102) ;
un appareil de rotation latérale (108, 308) couplé à la surface de support de personne (102), l'appareil de rotation latérale (108, 308) comprenant une pluralité de plans de support indépendamment rotatifs arrangés longitudinalement (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) et un actionneur de rotation latérale (136) couplé de manière opérationnelle à un ou plusieurs des plans de support (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) ;
une unité de commande (156) comprenant un processeur (410) et un support de stockage non transitoire lisible par machine comprenant une routine de thérapie dynamique, la routine de thérapie dynamique comprenant des instructions exécutables par le processeur (410) pour faire que l'unité de commande (156) contrôle le fonctionnement de l'appareil de rotation latérale (108, 308) en :

déterminant une durée maximale en décubitus dorsal ;
surveillant la durée réelle en décubitus dorsal d'un sujet humain positionné sur l'appareil de support de personne ; et
contrôlant l'actionneur de rotation latérale (136) pour maintenir la durée réelle en décubitus dorsal en dessous de la durée maximale en décubitus dorsal,

dans lequel l'unité de commande (156) est configurée pour calculer la durée maximale en décubitus dorsal sur la base d'une première valeur d'indice d'apnées-hypopnées (AHI) et d'une deuxième valeur d'AHI, dans lequel la première valeur d'AHI est déterminée pendant que le sujet humain est en décubitus dorsal et la deuxième valeur d'AHI est déterminée pendant que le sujet humain n'est pas en décubitus dorsal.

2. Système dynamique de support de personne (100, 400, 1100) selon la revendication 1, dans lequel l'actionneur de rotation latérale (136) comprend un dispositif électromécanique configuré pour entraîner la rotation latérale des plans de support indépendamment rotatifs (110, 112, 114, 310, 312, 314, 1104, 1108, 1112).

3. Système dynamique de support de personne (100, 400, 1100) selon la revendication 1 ou la revendication 2, dans lequel l'actionneur de rotation latérale (136) comprend une pluralité de vessies gonflables (116, 118, 120) soutenant les plans de support indépendamment rotatifs (110, 112, 114, 310, 312, 314, 1104, 1108, 1112) et une alimentation en air couplée aux vessies gonflables (116, 118, 120).

4. Système dynamique de support de personne (100, 400, 1100) selon l'une quelconque des revendications précédente, comprenant un capteur en communication avec l'unité de commande (156), dans lequel l'unité de commande (156) est configurée pour recevoir une valeur détectée du capteur et déterminer la durée maximale en décubitus dorsal sur la base de la valeur détectée.

5. Système dynamique de support de personne (100, 400, 1100) selon la revendication 4, dans lequel la valeur détectée

est indicative d'un indice d'apnées-hypopnées (AHI) du sujet humain surveillé.

6. Système dynamique de support de personne (100, 400, 1100) selon la revendication 4, dans lequel la valeur détectée est indicative d'un état de sommeil du sujet humain surveillé.

7. Système dynamique de support de personne (100, 400, 1100) selon la revendication 5, dans lequel l'unité de commande (156) est configurée pour ajuster la durée maximale en décubitus dorsal en réponse à la valeur détectée.

8. Système dynamique de support de personne (100, 400, 1100) selon la revendication 7, dans lequel l'unité de commande (156) est configurée pour augmenter la durée maximale en décubitus dorsal en réponse à la valeur détectée étant au-dessous d'une valeur seuil.

9. Système dynamique de support de personne (100, 400, 1100) selon la revendication 8, dans lequel l'unité de commande (156) est configurée pour diminuer la durée maximale en décubitus dorsal en réponse à la valeur détectée étant au-dessus d'une deuxième valeur seuil.

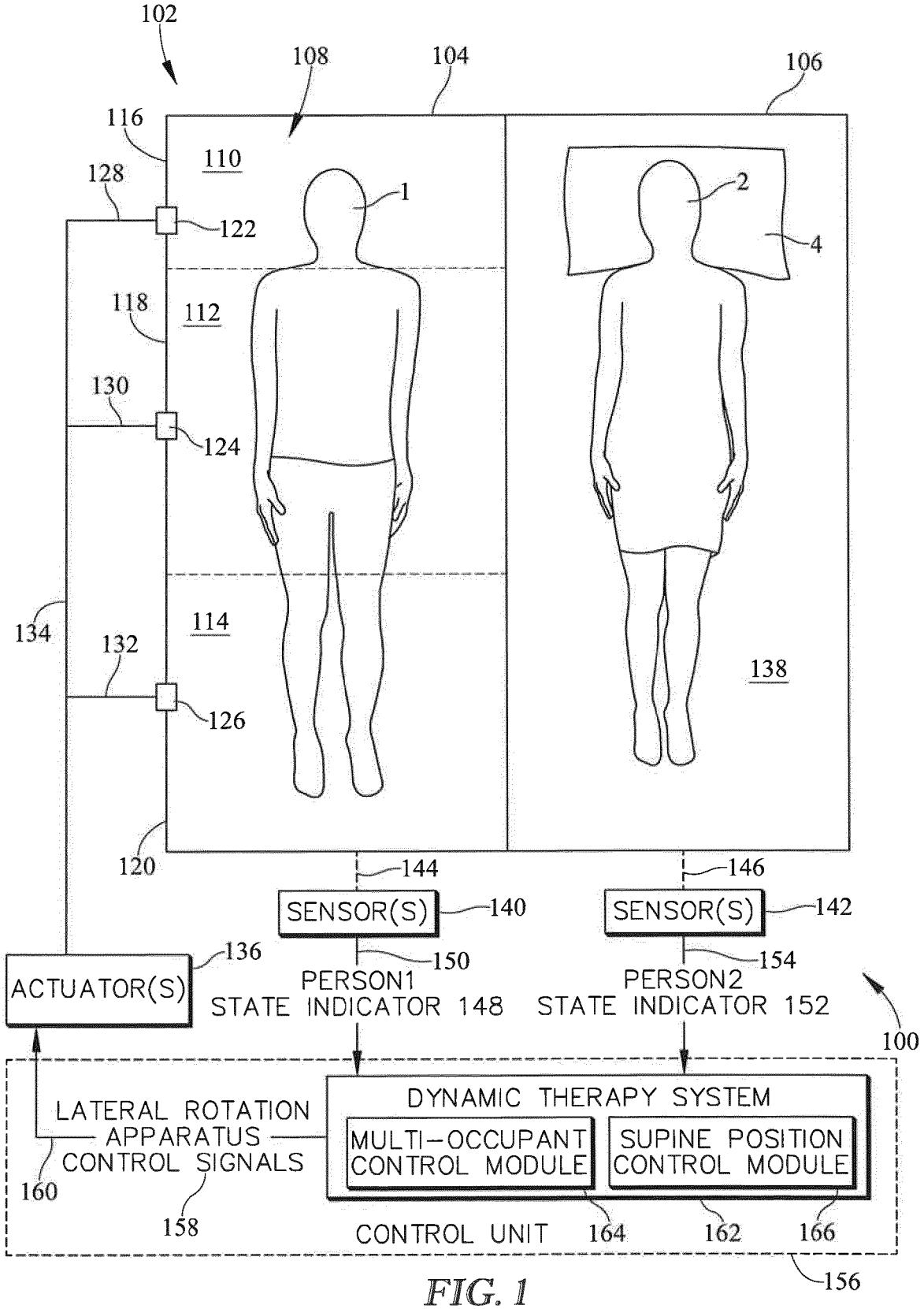
102
108
104
106
116
110
128
122
1
2
4
118
112
130
124
114
134
132
126
138
120
144
146
SENSOR(S)
140
SENSOR(S)
142
136
150
154
ACTUATOR(S)
PERSON1
STATE INDICATOR 148
PERSON2
STATE INDICATOR 152
100
DYNAMIC THERAPY SYSTEM
LATERAL ROTATION
APPARATUS
CONTROL SIGNALS
MULTI-OCCUPANT
CONTROL MODULE
SUPINE POSITION
CONTROL MODULE
160
158
CONTROL UNIT
164
162
166
156

FIG. 1

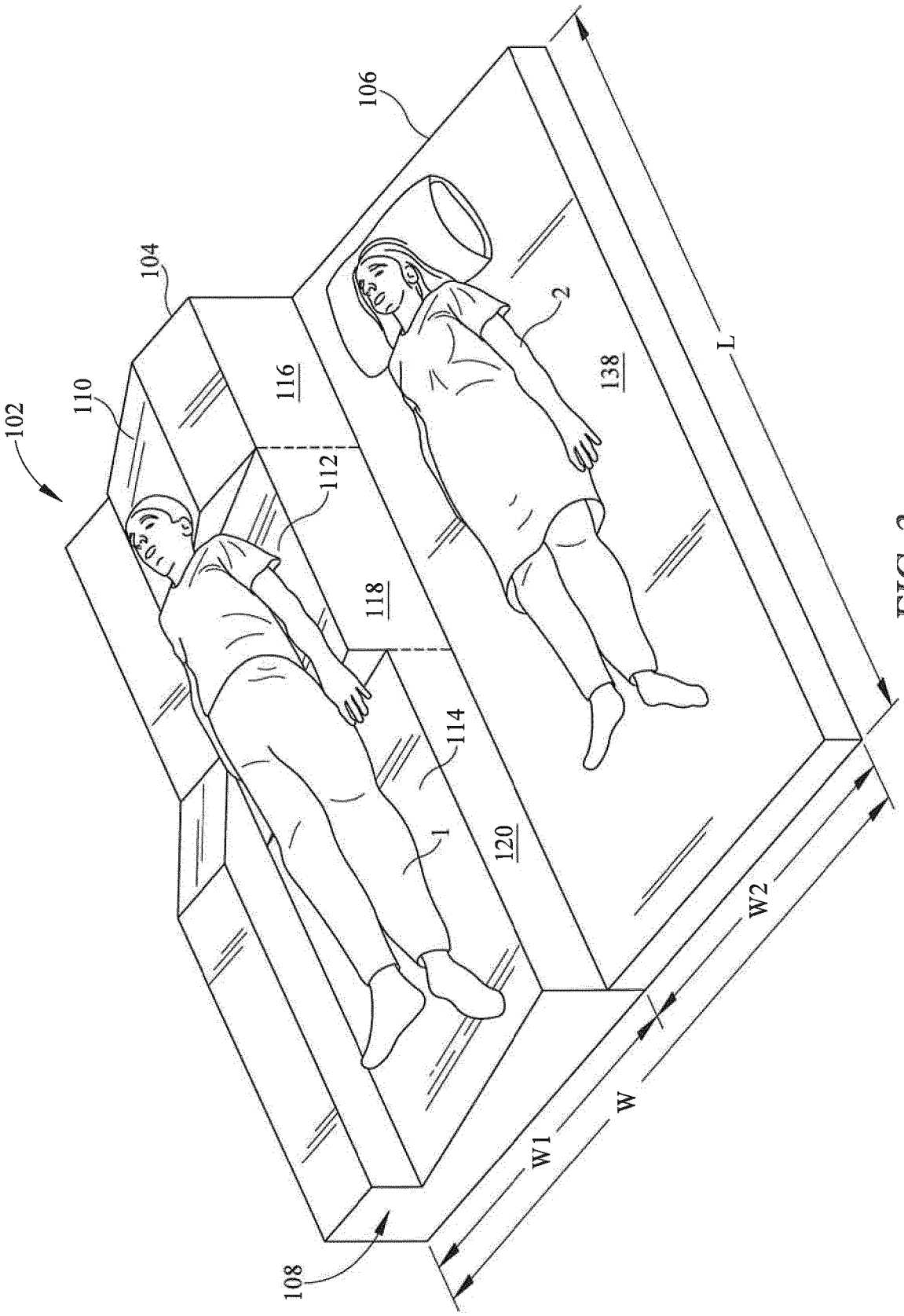

FIG. 2

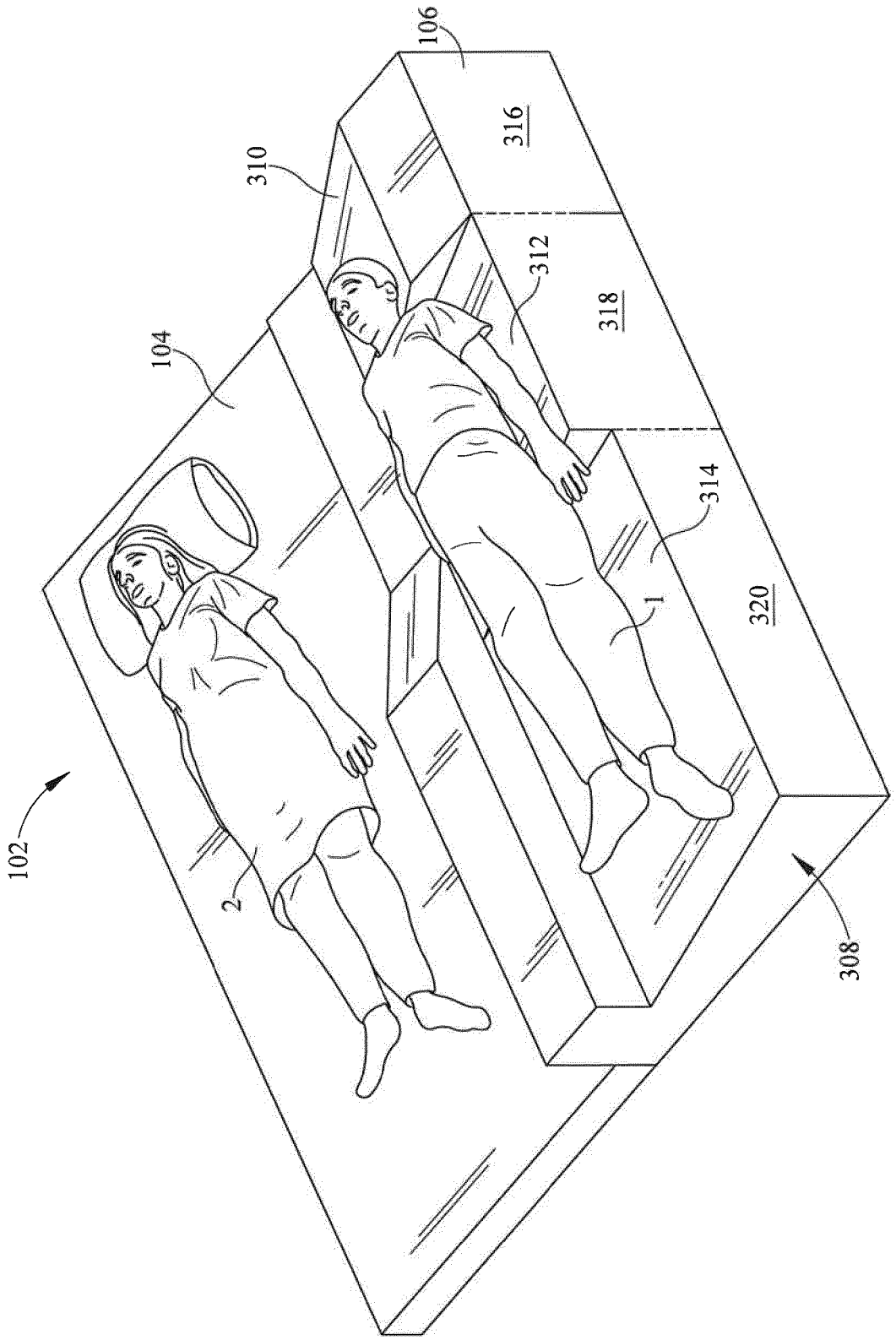

FIG. 3

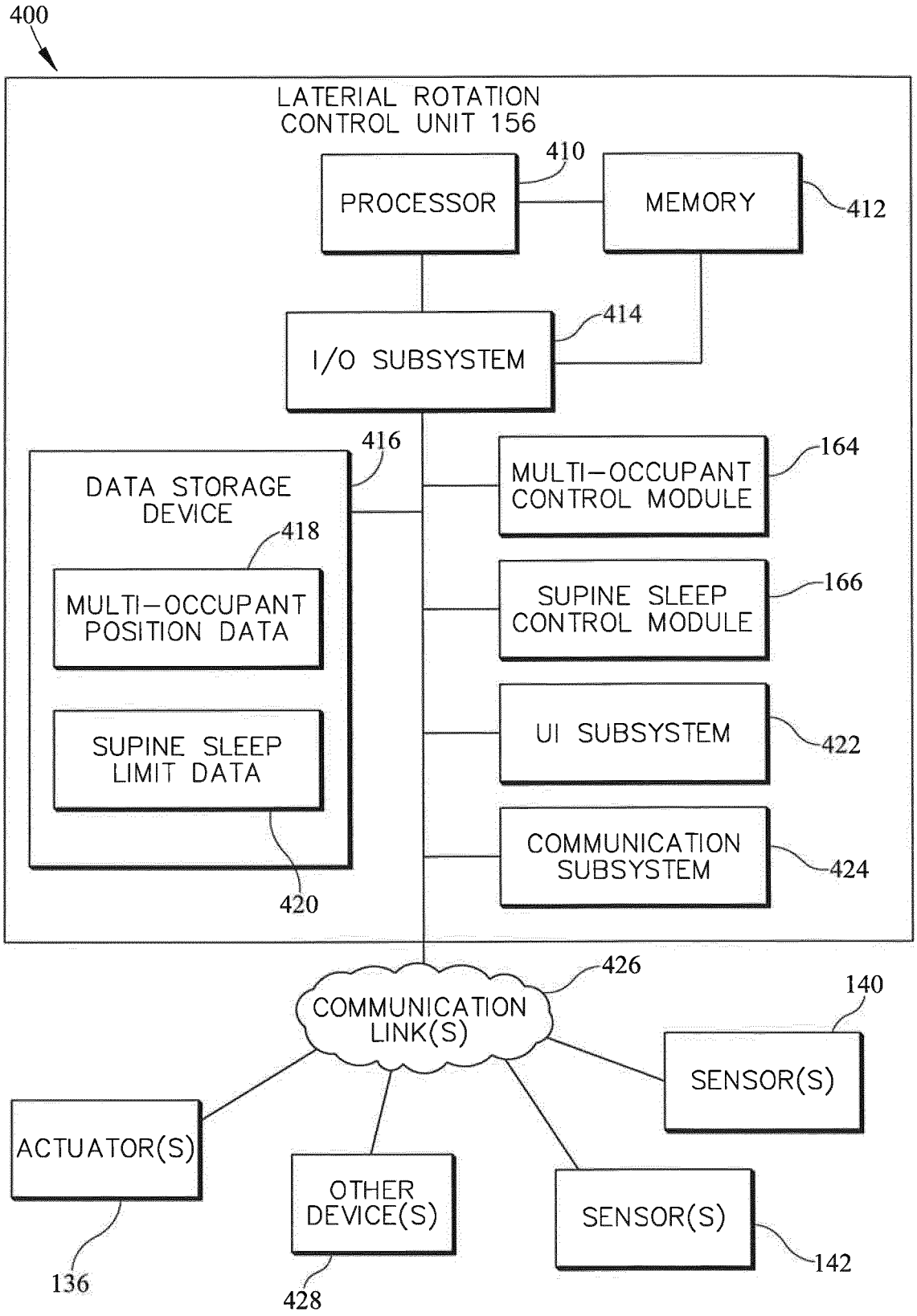
400
LATERIAL ROTATION CONTROL UNIT 156
410
PROCESSOR
MEMORY
412
414
I/O SUBSYSTEM
416
DATA STORAGE DEVICE
418
MULTI-OCCUPANT POSITION DATA
SUPINE SLEEP LIMIT DATA
420
MULTI-OCCUPANT CONTROL MODULE
164
SUPINE SLEEP CONTROL MODULE
166
UI SUBSYSTEM
422
COMMUNICATION SUBSYSTEM
424
426
COMMUNICATION LINK(S)
140
SENSOR(S)
ACTUATOR(S)
136
OTHER DEVICE(S)
428
SENSOR(S)
142

FIG. 4

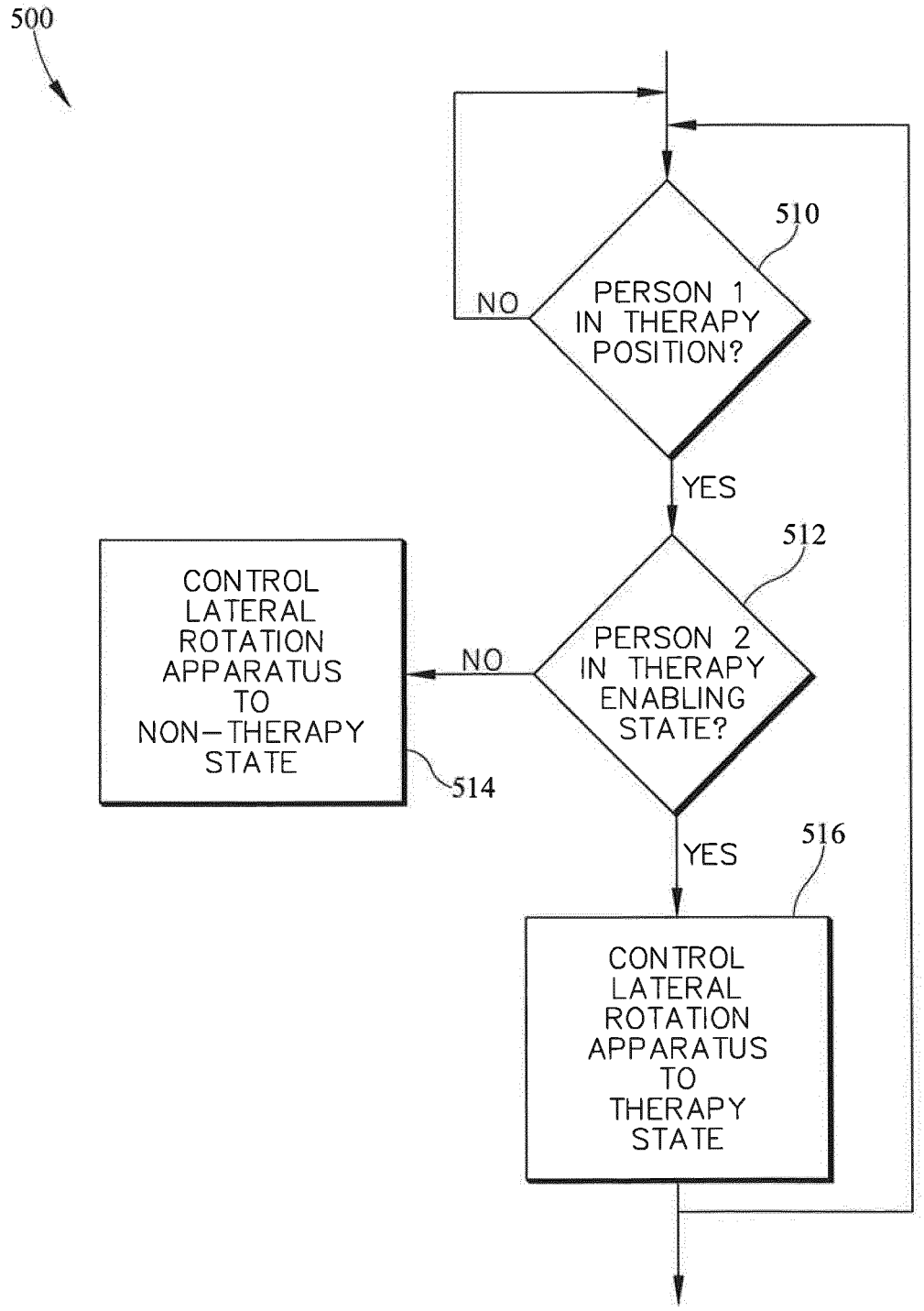
500
510
PERSON 1 IN THERAPY POSITION?
NO
YES
512
PERSON 2 IN THERAPY ENABLING STATE?
NO
CONTROL LATERAL ROTATION APPARATUS TO NON-THERAPY STATE
514
YES
516
CONTROL LATERAL ROTATION APPARATUS TO THERAPY STATE

FIG. 5

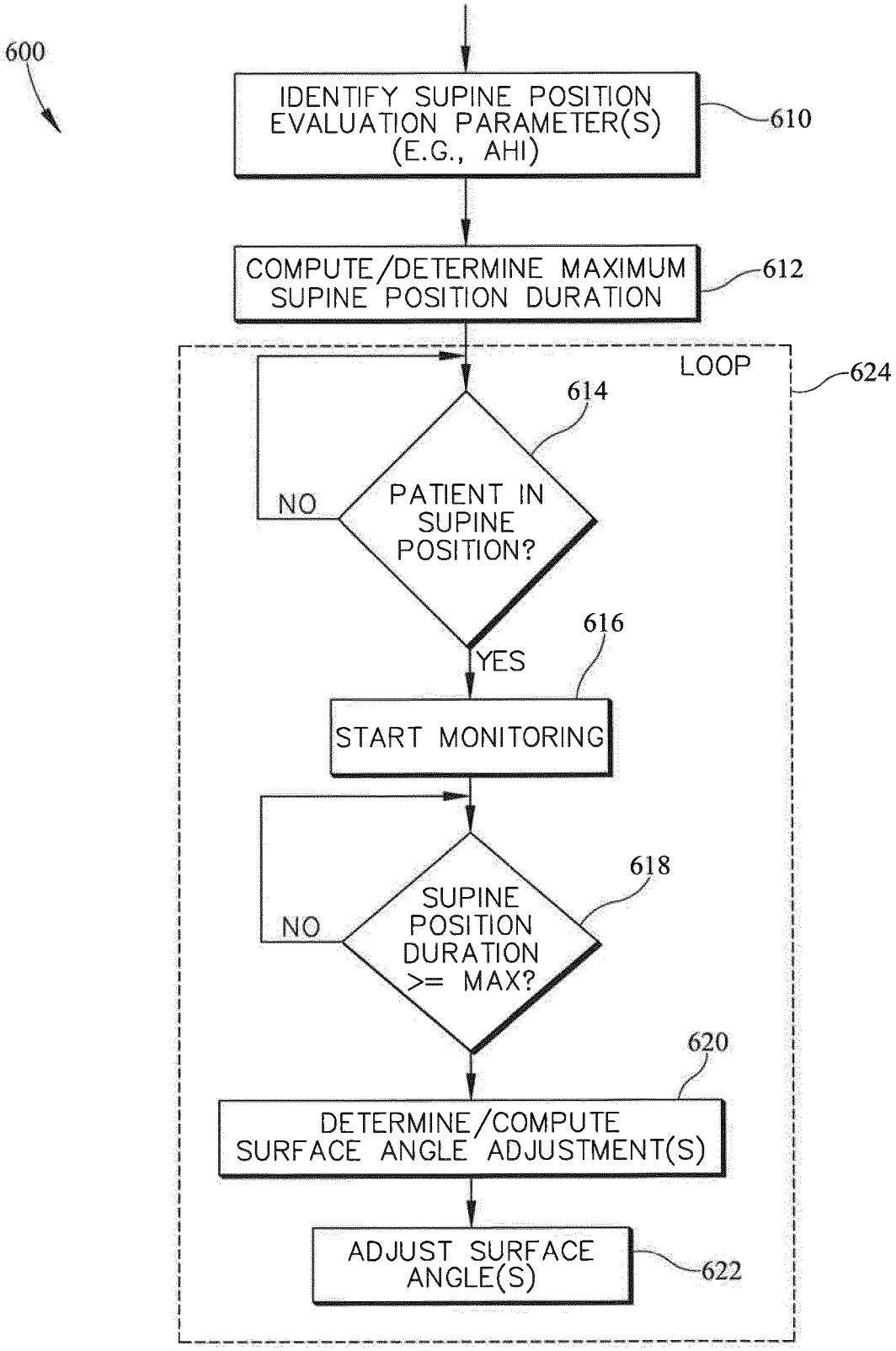
600
IDENTIFY SUPINE POSITION EVALUATION PARAMETER(S) (E.G., AHI)
610
COMPUTE/DETERMINE MAXIMUM SUPINE POSITION DURATION
612
LOOP
624
614
PATIENT IN SUPINE POSITION?
NO
YES
616
START MONITORING
618
SUPINE POSITION DURATION >= MAX?
NO
620
DETERMINE/COMPUTE SURFACE ANGLE ADJUSTMENT(S)
ADJUST SURFACE ANGLE(S)
622

FIG. 6

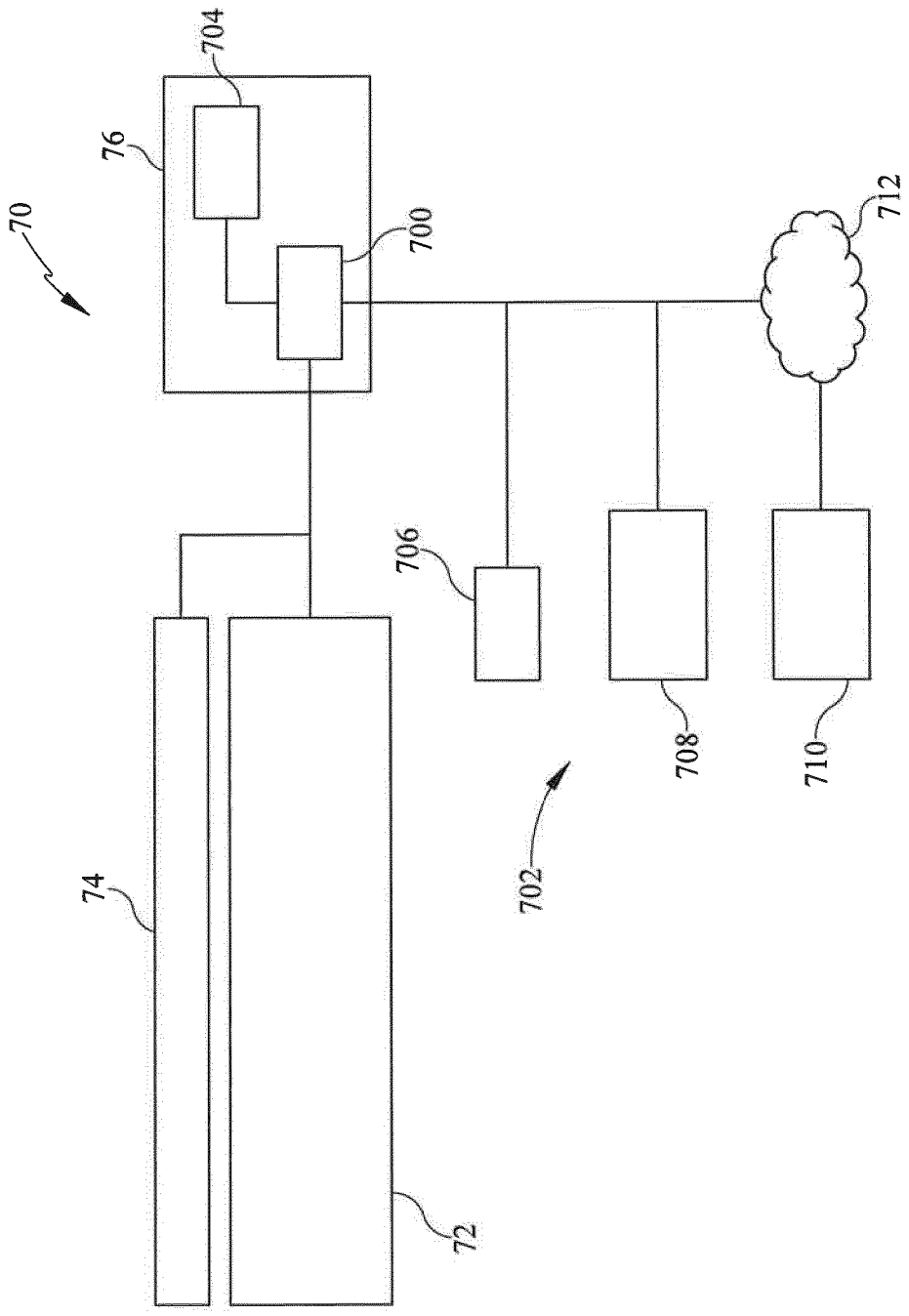

FIG. 7

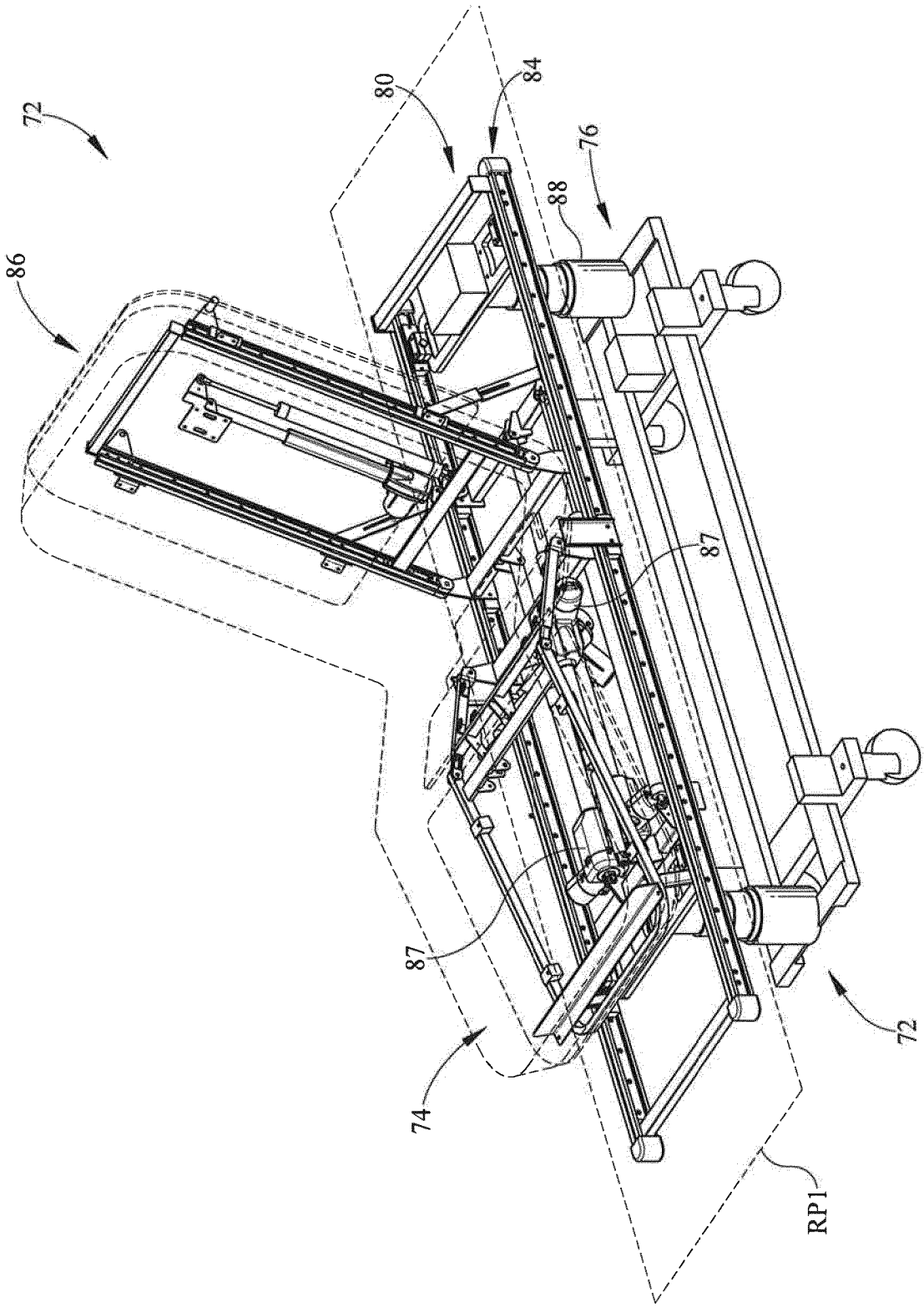

FIG. 8

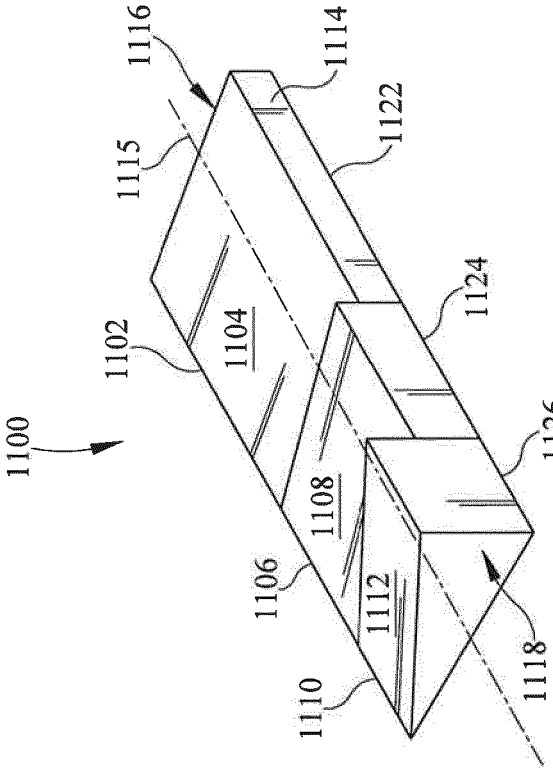

FIG. 10

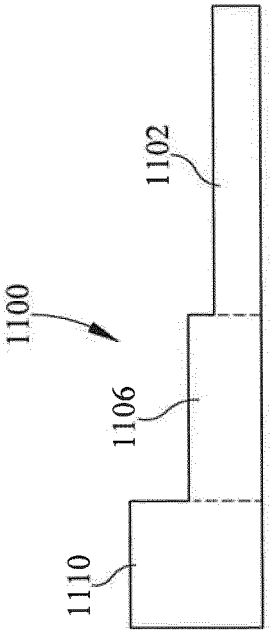

FIG. 11

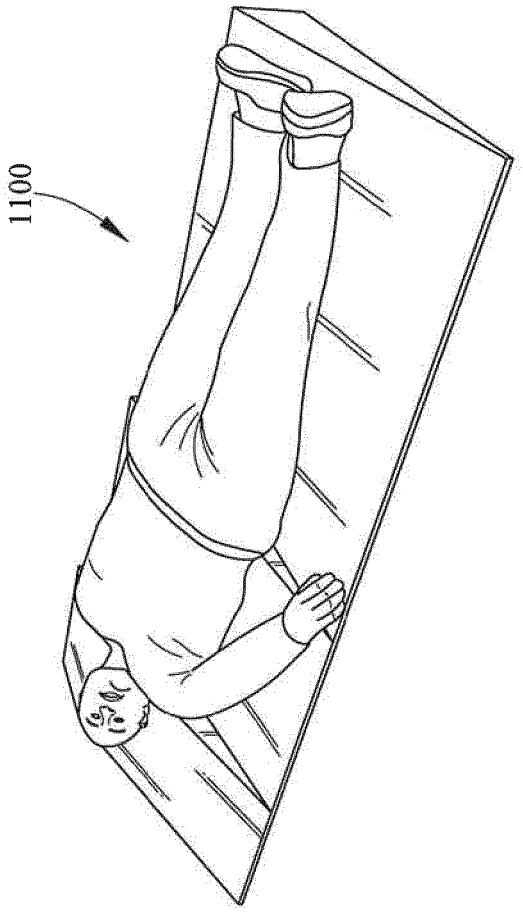

FIG. 9

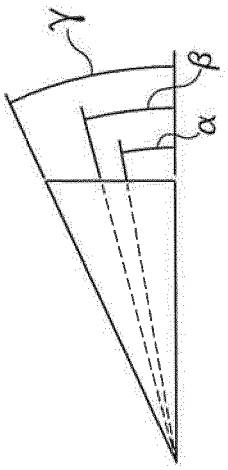

FIG. 12

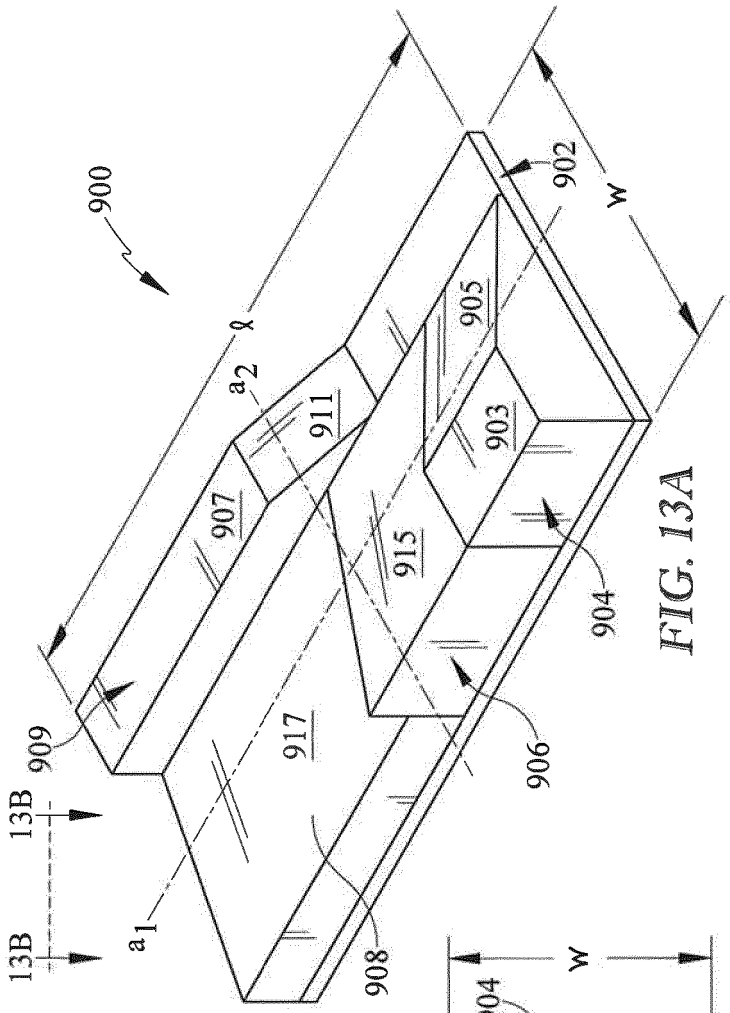

FIG. 13A

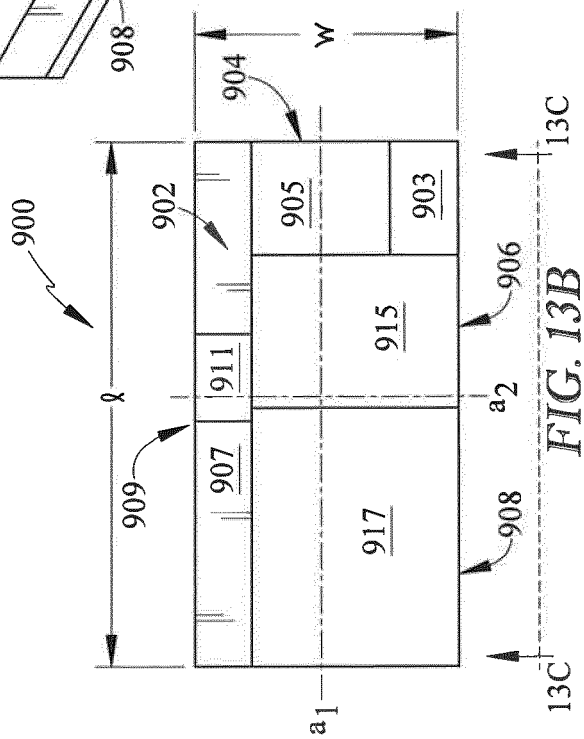

FIG. 13B

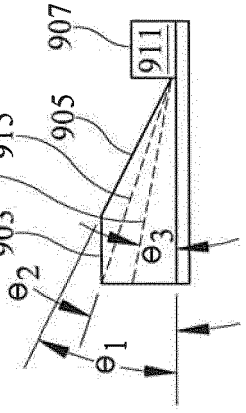

FIG. 13D

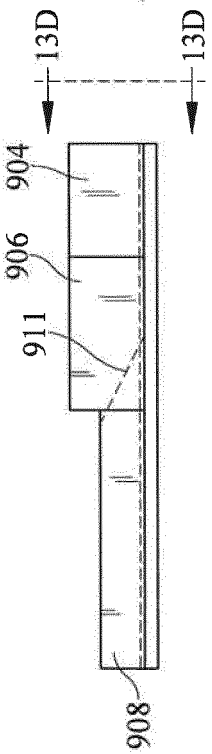

FIG. 13C

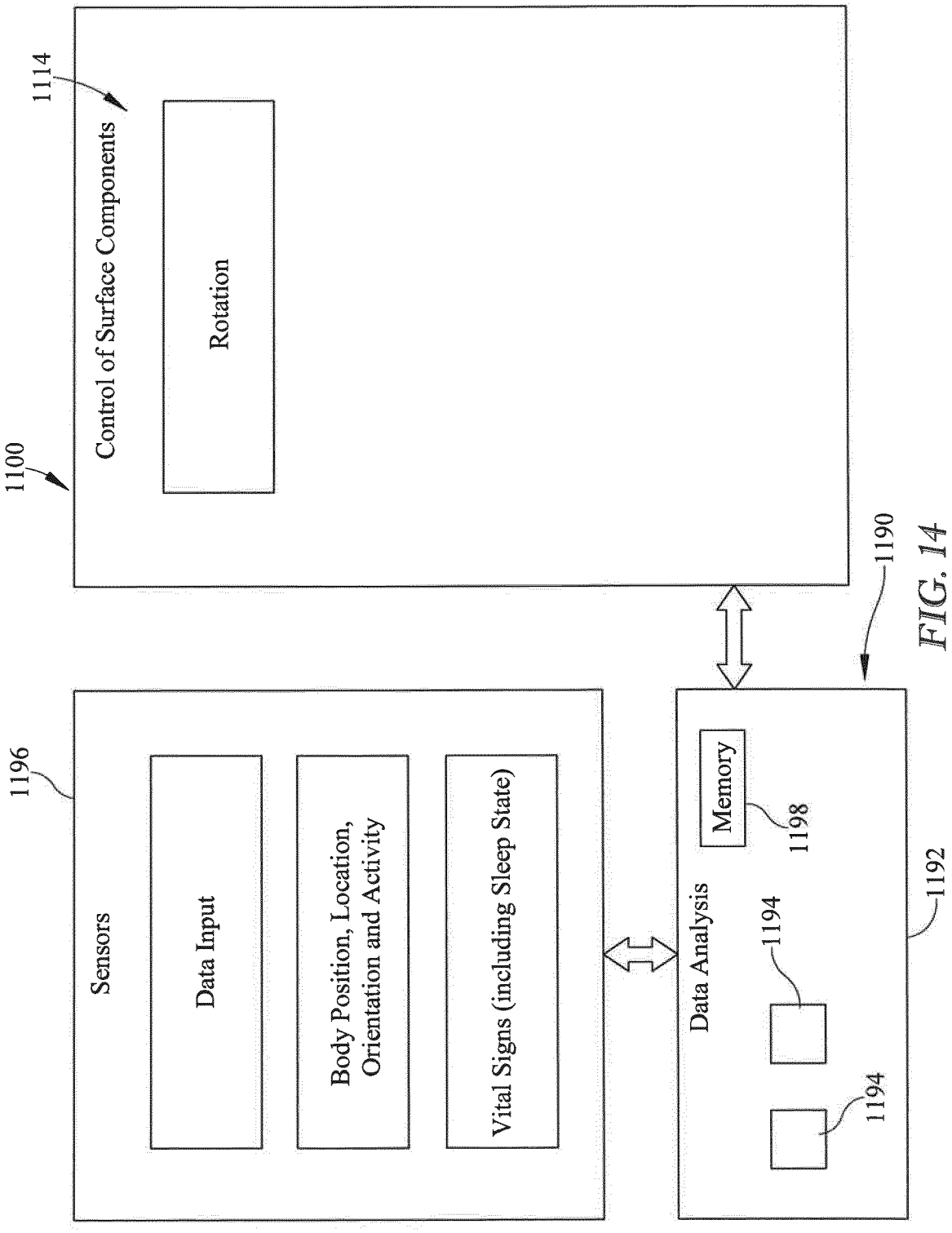
1100
1114
Control of Surface Components
Rotation
1190
1196
Sensors
Data Input
Body Position, Location, Orientation and Activity
Vital Signs (including Sleep State)
1192
Data Analysis
Memory
1198
1194
1194

FIG. 14

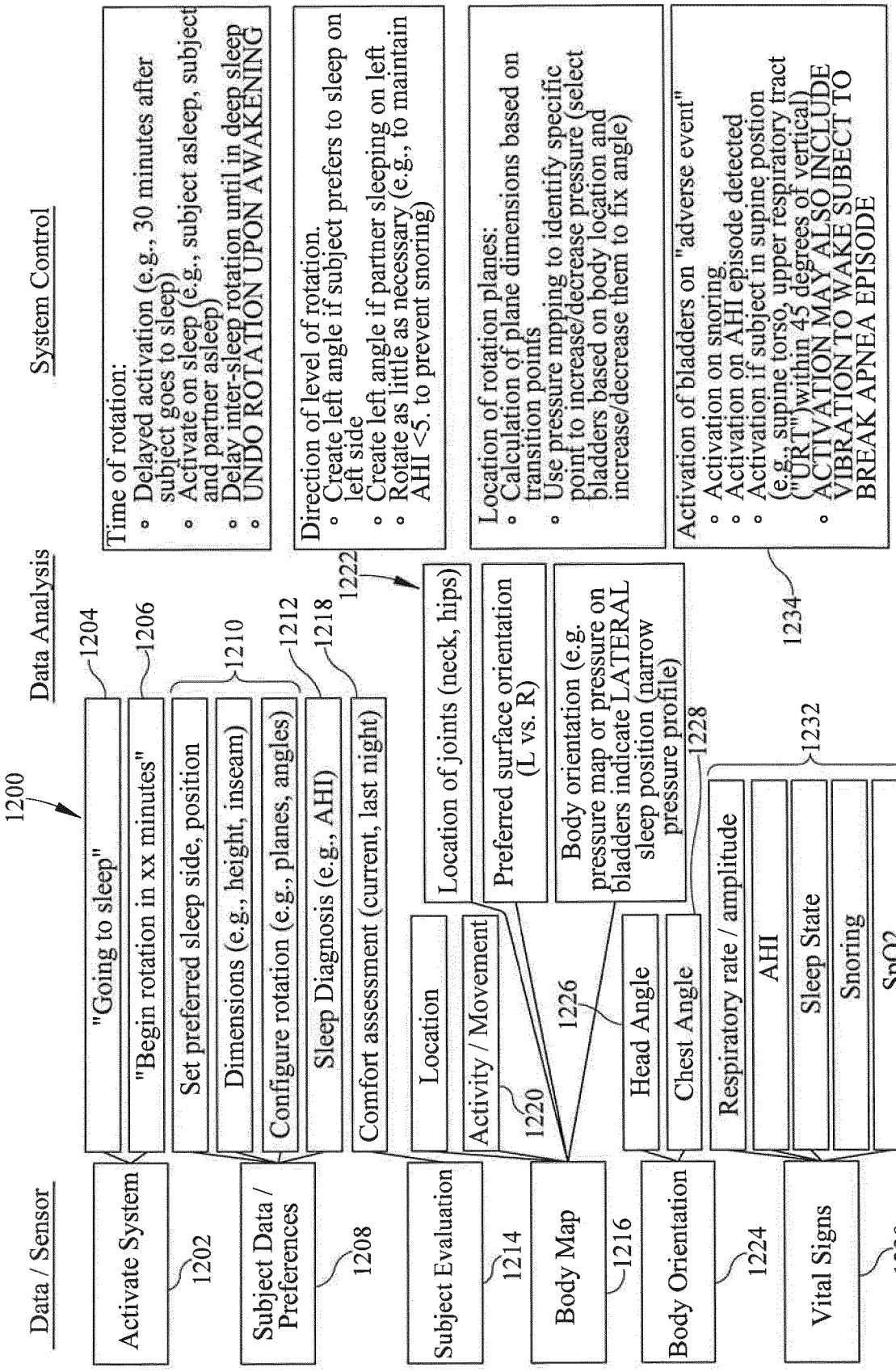
1200
Data / Sensor
Data Analysis
System Control
Activate System
1202
"Going to sleep"
1204
"Begin rotation in xx minutes"
1206
Subject Data / Preferences
1208
Set preferred sleep side, position
Dimensions (e.g., height, inseam)
1210
Configure rotation (e.g., planes, angles)
1212
Sleep Diagnosis (e.g., AHI)
1218
Comfort assessment (current, last night)
1222
Subject Evaluation
1214
Location
Activity / Movement
1220
Location of joints (neck, hips)
Preferred surface orientation (L vs. R)
Body Map
1216
1226
Body orientation (e.g. pressure map or pressure on bladders indicate LATERAL sleep position (narrow pressure profile)
Body Orientation
1224
Head Angle
Chest Angle
1228
Vital Signs
1230
Respiratory rate / amplitude
AHI
Sleep State
Snoring
SpO2
1232
1234
Time of rotation:
Delayed activation (e.g., 30 minutes after subject goes to sleep)
Activate on sleep (e.g., subject asleep, subject and partner asleep)
Delay inter-sleep rotation until in deep sleep
UNDO ROTATION UPON AWAKENING
Direction of level of rotation.
Create left angle if subject prefers to sleep on left side
Create left angle if partner sleeping on left
Rotate as little as necessary (e.g., to maintain AHI <5. to prevent snoring)
Location of rotation planes:
Calculation of plane dimensions based on transition points
Use pressure mpping to identify specific point to increase/decrease pressure (select bladders based on body location and increase/decrease them to fix angle)
Activation of bladders on "adverse event"
Activation on snoring
Activation on AHI episode detected
Activation if subject in supine postion (e.g., supine torso, upper respiratory tract ("URT") within 45 degrees of vertical)
ACTIVATION MAY ALSO INCLUDE VIBRATION TO WAKE SUBECT TO BREAK APNEA EPISODE

FIG. 15

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2014149392 A1 **[0001]**
- WO 2012129397 A1 **[0001]**
- US 2004103475 A1 **[0001]**
- US 2013042313 W **[0013]**
- US 2014018033 W **[0013]**
- US 45496114 **[0013]**
- US 498872 **[0013]**
- US 7515059 B, Price **[0058]**
- US 20110068928 A, Riley **[0058]**
- US 20120029879 A, Sing **[0058]**